Insect Pollinators Visiting Invasive Plant of Southernpart of Kathmandu Valley, Nepal

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Nepal

A dissertation submitted

in partial fulfillment of the requirements for the award of the degree of Master of Science in Zoology with special paper Entomology

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August, 2025

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Declaration

I hereby declare that the work presented in this dissertation **"Insect Pollinators Visiting Invasive Plant of Southernpart of Kathmandu Valley, Nepal"** has been done by myself and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by rerefencing to the author(s) or institution (s).

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This is to recommend that the dissertation entitled **"Insect pollinators Visiting Invasive Plant of Southernpart of Kathmandu Valley, Nepal"** has been carried out by **Kusum Upreti** for the partial fulfilment of Master's Degree of Science in Zoology with the special paper Entomology. This is her original work and has been carried out under my supervision. To the best of my knowledge, this dissertation work has been submitted for any other degree in any institutions.

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Certificate of Acceptance

This dissertation work submitted by Kusum Upreti entitled **"Insect Pollinators Visiting Invasive Plant of Southernpart of Kathmandu Valley, Nepal"** has been accepted as a partial fulfilment for the requirements of Master's degree of Science in Zoology with special paper Entomology.

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Abstract

The study was conducted to investigate insect pollinators visiting invasive plants of Southern part of Kathmandu valley. The search was conducted purposively in such area which consists of extent number of mixed flower by making a plot about 30/30m at a distance of 100m and moving along the transect line. Insect pollinator were collected through sweeping net method. Three plot was made at one site and insects were observed for 30 minutes. The study was carried out in both summer and autumn season. A total of 271 individual were observed from three orders and twelve families of pollinator was recorded in both season. Out of which Hymenoptera order was most dominant in both season followed by Lepidoptera and Diptera. In summer, *Lantana camara* was visited by the highest number of pollinators. While in autumn season *Bidens pilosa* was the most prevalent invasive plant, with Hymenoptera species as the most frequent visitors. The most visitor species include Apis cerana, *Bombus* spp., *Amegilla* spp., *Parapolybia* spp, and *Syntomoides imaon*, *Polistes* spp., *Episyrphus* spp., *Eristalis* spp., *Eristalinus* spp., *Pieris canidia* and various other butterflies. In both the season Diptera were less observed and the invasive plant *Ipomoea carnea*, *Alternanthera philoxeroides* and *xanthium* strumarium though less prevalent in the study area. The findings of this study provide valuable data for government agencies, academic institutions, and stakeholders, contributing to further research on insect pollinators and invasive plant species.

Keywords: Insect Pollinators; Invasive Plants; Kathmandu Valley; Seasonal Variation; Hymenoptera Dominance

शोधसार

यो अध्ययन काठमाडौं उपत्यकाको दक्षिणी भागमा पाइने मिचाहा वनस्पतिहरूमा परागसेचक किराहरुको अनुसन्धान गर्नका लागि गरिएको थियो। अनुसन्धान त्यस्ता स्थानहरूमा गरिएको थियो, जहाँ प्रशस्त संख्यामा मिश्रित फूलहरू पाइन्छन्। यसका लागि जम्मा १० ओटा site जसमध्ये ५ दक्षिणकाली र ५ चन्द्रगिरि क्षेत्रमा स्थापना गरिएको थियो। प्रत्येक site मा ३ ओटा ३०m/३०m को प्लट बनाएर तिनमा ट्रान्सेक्ट लाइन बनाउदै, ति ट्रान्सेक्टहरुमा १m/१ m को सवप्लट बनाइयो । परागसेचक किराहरु ति ट्रान्सेक्ट लाईनमा हिन्दै खोज्न थालियो र १m /१m सवप्लटमा भएका फूलहरुको संख्या गन्दै टिपोट गरियो। परागसेचक किराहरु स्वीपिङ नेट (sweeping net) विधिबाट संकलन गरिएको थियो। हरेक प्लटमा ३० मिनेट अवलोकन गरियो। यो अध्ययन गर्मी (summer) र शरद (autumn) दुवै मौसममा गरिएको थियो। दुवै मौसममा गरी जम्मा २७१ प्रजातिका परागसेचक किराहरु अवलोकन गरिएका थिए, जसमध्ये ३ वटा order र १२ वटा family अन्तर्गत वर्गीकृत थिए। तीमध्ये Hymenoptera order दुवै मौसममा सबैभन्दा धेरै संख्यामा देखिएका थिए, जसपछाडि क्रमश Lepidoptera र Diptera रहेका थिए। गर्मीमा *Lantana camara* मा सबैभन्दा धेरै परागसेचक किराहरु पाइए भने शरद मौसममा *Bidens pilosa* प्रमुख मिचाहा वनस्पति थियो, जसमा सबैभन्दा धेरै Hymenoptera वर्गका परागसेचक किराहरु भेटिए। सबैभन्दा धेरै देखिएका प्रजातिहरूमध्ये *Apis cerana*, *Bombus* spp., *Amegilla* spp., *Parapolybia* spp., *Syntomoides imaon*, *Polistes* spp., *Episyrphus* spp., *Eristalis* spp., *Eristalinus* spp., *Pieris canidia* र विभिन्न अन्य पुतली प्रजातिहरू समावेश थिए। दुवै मौसममा Diptera वर्गका परागसेचक किराहरु निकै कम संख्यामा देखिए। *Ipomoea carnea*, *Alternanthera philoxeroides* र *Xanthium* strumarium वनस्पतिहरू अध्ययन क्षेत्रमा कम मात्रामा पाइएका थिए। यस अध्ययनका परिणामहरूले सरकारी निकायहरू, शैक्षिक संस्थाहरू र सरोकारवालाहरूलाई उपयोगी जानकारी प्रदान गर्नेछ र मिचाहा वनस्पति तथा परागसेचक किराहरुको थप अनुसन्धानका लागि सहयोग पुऱ्याउनेछ।

मुख्यशब्दहरू: परागसेचक किराहरु; मिचाहा वनस्पति; काठमाडौं उपत्यका; मौसमी विविधता; Hymenoptera को प्रभुत्व।

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1. Introduction

1.1 Background

Pollination is a vital ecological service essential for food security, plant reproduction, and biodiversity (Maggi et al., 2023; Peixoto et al., 2022). It plays a significant role in maintaining plant variety, which is essential for conserving biodiversity (Senapathi et al., 2015). For flowering plants, the process of pollination is essential to ensure the formation of both fruits and seeds (Barrios et al., 2016; Weissmann & Schaefer, 2017; Lázaro et al., 2013). This process takes place when pollinators, such as insects, transfer pollen from the anther to the stigma, facilitating fertilization (Albano et al., 2009; Flanagan et al., 2009; Lázaro et al., 2013). Nearly nine out of every ten flowering plant species depend on insects to perform the vital task of pollination (Engel & Irwin, 2003). Of these insects, bees are the most important pollinators (Potts et al., 2010; Winfree et al., 2008)), primarily as they feed on floral products for the whole of their lifecycle.

Bees and wasps (Hymenoptera), butterflies and moths (Lepidoptera), beetles (Coleoptera), and hoverflies belonging to the family Syrphidae (Diptera) represent the primary groups of pollinators (Stanley, 2013). These insects detect nectar and pollen by responding to various floral characteristics such as fragrance, form, dimensions, and coloration (Chittka & Raine, 2006). Diurnal pollinators like bees have strong color vision and are especially attracted to blue or violet flower (Reverté et al., 2016). Blue flowers attract more visitors, especially bumblebees, because they offer higher sugar rewards in the form of nectar compared to other flowers (Dyer & Chittka, 2004). While some studies have found butterflies to be ineffective pollinators (Goldblatt & Manning, 2007), others describe them as selective pollinators, and pollinate only those plant species which possess long floral tubes (Johnson & Bond, 1994). Hoverflies, although limited in their foraging range, are capable of transferring a wide variety of pollen grains (Lucas et al., 2018).

From the pollinators’ perspective, exotic or invasive plants may represent new sources of food (Tourbez et al., 2025). Their attractiveness, availability, and nutritional rewards influence how often they are used by different pollinators (Carvalheiro et al., 2014). While exotic plants are generally neither strongly favored nor completely avoided (Morandin & Kremen, 2013), some species can attract certain pollinators. These plants can provide alternative nectar and pollen sources, especially for generalist pollinators. Generalist bees, which forage on a wide variety of floral resources, are more likely to utilize invasive plant species than specialist bees with limited dietary ranges (Lopezaraiza-Mikel et al., 2007; Padrón et al., 2009; Tepedino et al., 2008). Similarly, social bumblebees are typically more abundant in habitats dominated by invasive plants compared to solitary bee species (Nienhuis et al., 2009). This suggests that invasive plants may benefit some pollinators, though they can still disrupt native plant–pollinator networks.

Invasive alien plants are one of the main reasons why pollinator communities and their interactions with native plants are changing (Vanbergen et al., 2018). These plants grow rapidly and spread widely, causing significant damage to native species and habitats worldwide (Ameka & Ernest, 2019). They compete with native plants for resources like sunlight, space, nutrients, pollinators, and animals that spread seeds (Barton & Fortunel, 2023). Invasive plants can negatively affect pollinators if their nectar or pollen is unsuitable or if they replace important native flowering plants (Bjerknes et al., 2007; Stout & Morales, 2009).This can lead to reduction in both the abundance and diversity of pollinators by altering plant pollinator networks (Bjerknes et al., 2007; Hanula & Horn, 2011; Moroń et al., 2009; Stout & Morales, 2009). However, some invasive species that depend on insect pollination can be accepted by local pollinators and provide abundant nectar and pollen resources (Bartomeus et al., 2008; Russo et al., 2016; Traveset & Richardson, 2014). In such cases, these invasive species may temporarily increase pollinator numbers and diversity by offering a new food sources (Russo et al., 2019; Stout & Tiedeken, 2017). Invasive plants may monopolize pollinators, reducing visitation to native species, while invasive pollinators can outcompete native ones, leading to declines in pollinator richness and the disruption of specialized pollination (Morales et al., 2017; Stout & Tiedeken, 2017). Although invasive species are generally viewed as threats to biodiversity, some invasive plants can provide floral resources that support pollinators, particularly generalists, in degraded habitats (Kovács-Hostyánszki et al., 2022). This can lead to increased pollinator visitation and activity, though often at the cost of native plant pollinator interactions (King & Sargent, 2012).

Environmental conditions have a strong effect on the relationship between plants and pollinators. One of the most important factors is seasonality, which controls when different plants bloom (Memmott et al., 2007). Bee and other pollinator populations depend on flowers for pollen and nectar, which are their main sources of food (Roulston & Goodell, 2011). The amount and type of flowers available can affect how well pollinators survive, grow, and reproduce, and where they are found (Carvell et al., 2017; Eckerter et al., 2022; Grandgirard et al., 2002; Woodard & Jha, 2017). The availability of these resources changes with the seasons because different plants flower at different times (Baude et al., 2016; Hicks et al., 2016). As a result, the number and activity of pollinators also change throughout the year.

This study is expected to a foundational understanding that will support future research on insect pollinators associated with invasive plant species. Moreover, the findings will be valuable for ecologists and conservationists in better understanding the interaction between invasive species and pollinators and how these relationships influence local ecosystems. Some invasive plants can provide abundant nectar and pollen, which may increase pollinator abundance and diversity. Understanding how these species interact is key to managing invasive plants and protecting pollinators successfully. Therefore, the main objective of this study was to identify the insect pollinators associated with invasive plant species in southern part of the Kathmandu valley, Nepal.

1.2 Significance of the study

Biological invasions are one of the main drivers of global change and have negatively impacted all biomes and trophic level (Vilà et al., 2011). While most introduced species fail to establish, or remain in small naturalized populations (referred to as exotic species), some become invasive and rapidly increase in abundance (Pysek et al., 2004). However, for pollinators, exotic plants can serve as new food sources. Under certain conditions, some insect-pollinated invasive plants can integrate into pollination networks and attract a variety of pollinators (Bartomeus et al., 2008; Russo, 2016; Traveset & Richardson, 2014). These plants could offer plentiful food sources, which might lead to a rise in both the number of pollinators and the variety of species present (Russo et al., 2019; Stout & Tiedeken, 2017).

Very few studies on Pollinator and Invasive species have been carried out in Nepal. Habitat loss due to rapid urbanization, agricultural expansion and loss of natural habitats, Climate change affects the flowering time and pollinator activity. While invasive plants can have negative effects on native ecosystems, they also offer benefits to pollinators by serving as alternative food sources. Their availability, attractiveness, nutritional value, and unique characteristics influence their use by different pollinators (Carvalheiro et al., 2014). This study aims to identify insect pollinators visiting invasive plants in the southern part of the Kathmandu Valley. The findings will enhance understanding of how these species interact with pollinators, contributing to pollination ecology, conservation efforts, and invasive species management.

1.3 Objectives

1.3.1 General objective

To assess the insect pollinators associated with invasive flowering plant species in of the southern part of Kathmandu valley.

1.3.2 Specific objectives

1. To identify the insect pollinators   associated with invasive plant species.
2. To invent the seasonal variation (summer and autumn season) of insect pollinator visiting invasive plants.

1.4 Research question

- Is there seasonal variation in insect pollinators visiting invasive plant species?
- Do different invasive plant species attract different types of insect pollinators?

2. Literature review

2.1 Diversity of invasive Plants in Nepal

In Nepal, Pathak et al., (2021) identified 26 species of invasive alien plants, with *Bidens pilosa* being the most widespread (63%), followed by *Ageratum houstonianum* (61%) and *Lantana camara* (44%). Meanwhile, (B. Shrestha, 2021) documented the presence of 29 invasive plant species in Nepal. The study focused on Kathmandu by Paudel et al., (2021) documented 13 invasive alien plant species, among which *Ageratum houstonianum* exhibited the highest frequency, while *Lantana camara* had the most extensive ground coverage.

2.2 Pollinator diversity on invasive plant species

Baboo et al., (2019) recorded 26 species in Kerala, India. *Amegilla zonata L*. from hymenoptera and Butterflies Species belonging to Family Papilionidae followed by Nymphalidae and Hesperidae from Lepidoptera were the most frequent Pollinator to *Lantana camara*. Milne, (2016) investigated the diversity of flower visiting arthropods associated with the flowers of *L. camara* in Thailand. The study documented 27 taxonomic groups of arthropods either visiting or inhabiting the plant's flowers. Bees (32%) and butterflies (28%) were the most frequent visitors. Among the recorded arthropods, bees, butterflies, and thrips were identified as key potential pollinators of *L. camara*.

Mirge and Tidke, (2022), studied on the floral biology of Ipomea obscura in india. The sudy observed that the flowers of *Ipomoea obscura* are pollinated by insects such as *Lasius niger*, *Apis florae*, *Musca domestica*, *Apis mellifera*, and various *Camponotus* species. A study by Ngongolo et al., (2014) in Tanzania observed a total of 182 insect visitors on *Ageratum conyzoides*, with Hymenoptera comprising the vast majority (96.3%) of the recorded individuals. In contrast, syrphid flies represented only a small fraction of the total, accounting for just 0.5%. Other species observed visiting were *Cercesis sp*, *Chrysoma sp*, *Componotus sp*, *Hesperida sp* and *Apis mellifera*. Budumajji & Solomon Raju, (2018) found bees 27%, wasps 6%, bee-fly 4% and butterflies 63% of total foraging visits in *Bidens pilosa* L. during the study in Taiwania. Figueroa-Castro et al., (2016) recorded 96 visitor species in three invasive plant of Asteraceae family; *Flaveria ramosissima, Florestina pedata, and Parthenium bipinnatifidum* during the study in Mexico. The research revealed that the predominant pollinators were from the orders Hymenoptera, Diptera, Lepidoptera, Coleoptera, and Hemiptera. In Brazil, Grombone-Guaratini et al., (2004) investigated the reproductive biology of *Bidens pilosa*. The result showed that Lepidoptera and Hymenoptera were the most common visitors in *Bidens pilosa*. Hymenopterans, particularly solitary bees, accounted for 67% to 93% of visits, while butterflies mainly from the family Nymphalidae contributed between 1.5% and 26%, making them the primary floral visitors alongside bees. While, Dipteran species from the Syrphidae family were the least frequently observed visitors to *Bidens pilosa*. Ojija et al., (2019) recorded 1209 insects visits in *Parthenium hysterophorus* during their study in Brazil. Among the Pollinator observed, Hymenoptera and Diptera were the leading groups, with *Apis mellifera* identified as a most common flower visitor. In a study conducted in the United States, Schemske, (1976) examined butterfly visitation patterns on *Lantana camara* and *Lantana trifolia*. The results showed that *L. camara* predominantly attracted larger butterfly species, while *L. trifolia* was more frequently visited by smaller butterflies. The study further revealed that visitation rate of the butterfly significantly different based on the floral character.

Mukherjee et al., (2022) investigated how the invasive species *Lantana camara* contributes to the preservation and support of native butterfly populations in India. The study revealed that butterfly species richness was highest in areas where *Lantana* was most abundant and lowest in areas with minimal *Lantana* presence. The butterflies recorded from all sites belonging to the family *Nymphalidae* followed by *Piredae, Papilionidae, and Hesperiidae.* Study further revealed there was a strong positive link between *Lantana* abundance, butterfly numbers, and species richness. Pei et al., (2023) investigated the seasonal floral preferences of European honey bees and native bumble bees in North American grasslands dominated by exotic plant species. The study found that honey bees predominantly foraged on exotic flowers, while bumble bees showed a strong preference for native flora. Mallick & Gupta, (2024) examined how butterflies choose among different color forms of *Lantana camara* flowers. They documented twelve butterfly species in total, representing the families Hesperiidae, Papilionidae, Nymphalidae, and Pieridae. Of these, five species were from Nymphalidae, four from Papilionidae, and one each from Hesperiidae and Pieridae. The findings reveal that a clear preference among butterflies for pink and pink-yellow *Lantana camara* flowers, suggesting that floral colour plays a significant role in pollinator foraging behavior.

Baskett et al., (2011) investigated the impact of two invasive plants baby's breath (*Gypsophila paniculata*) and spotted knapweed (*Centaurea maculosa*) on pollinators visiting *Cirsium pitcheri*, a rare native plant in the Lake Michigan sand dunes. They found that invaded areas attracted five times more pollinators than uninvaded sites. However, this did not benefit *C. pitcheri*, as increased pollinator activity led to more interspecific pollen transfer and reduced pollination success. They further concluded that Removal of the invasive species improved native plant richness and restored pollinator visitation to *C. pitcher* underscoring the indirect but significant impacts of invasive species on native pollination system.

2.3 Seasonal variation of insect pollinator

Baboo et al., (2019) Studied insect pollinators of *Lantana camara* at two different altitudinal sites at southern Western Ghats in India. A total of 29 insect species were recorded, mainly Lepidopterans and Hymenopterans, with butterflies identified as likely pollinators, with greater visitor diversity found at higher elevations. The study revealed Environmental factors significantly influenced visitation patterns, humidity was positively correlated with the number of flowers visited, while higher temperatures were linked to shorter visit durations. Bashir, (2015) explored the seasonal variation of pollinators in relation to their abundance and diversity in southern Punjab, India. The research focused on two main insect orders, Diptera (flies) and Hymenoptera (bees and wasps). Result indicated that files and bees were active throughout the year, wasp's ceased activity during the winter months when temperatures fell down below 20°c. A total of 42 fly species, 68 bee species and 57 wasp species were observed, with peak abundance and richness of bees in summer and wasps in spring and autumn. Harris et al., (2024) explored the seasonal variation in the general availability of floral resources for pollinators in northwest Europe. A review of 18 studies mostly using honeybees as indicators, found that floral resource availability for pollinators varies seasonally. Result indicated that spring and early summer (especially April) more likely to be categorized as favorable seasons for foraging than late summer or autumn (particularly August). Panta, (2021) investigated the seasonal patterns of flowering plants utilized by bees in the Coronation Garden of Tribhuvan University, Kirtipur. A total of 197 plant species were identified as bee forage, including wild, ornamental, horticultural, and agricultural types. Spring had the highest number of bee plants (118), followed by summer (116), and autumn had the least (83), making spring 2016 the most favorable season for bee activity.

3. Materials and methods

3.1 Study area

This investigation was performed in the localities of Chandragiri and Dakshinkali. Dakshinkali is located in the Kathmandu District at an elevation of 1509 meters, with coordinates 27°37′11″N and 85°15′04″E (Shrestha et al., 2018). It is renowned for the Dakshinkali Temple, a prominent Hindu shrine dedicated to Goddess Kali, situated approximately 22 kilometers from Kathmandu. The Dakshinkali Municipality offers a variety of tourism opportunities, including its scenic natural landscapes, traditional rural life, and both Hindu and Buddhist religious sites (Kafle, 2022). Whereas, Chandragiri Hills, located in the mid-hill area southwest of Kathmandu Valley, falls within the boundaries of Chandragiri Municipality. It lies at 27.6672°N latitude and 85.2058°E longitude, with an elevation ranging from about 1300 to 2540 meters. It is situated about 16 kilometers from center of Kathmandu and covers area of about 11 square kilometers. At the top of the hill is the Bhaleshwor Mahadev Temple, a well-known religious and tourist spot that offers beautiful views of the Kathmandu Valley and the Himalayan Mountains. The climate in this area ranges from subtropical to temperate, and the hills are covered with a variety of mixed forests.

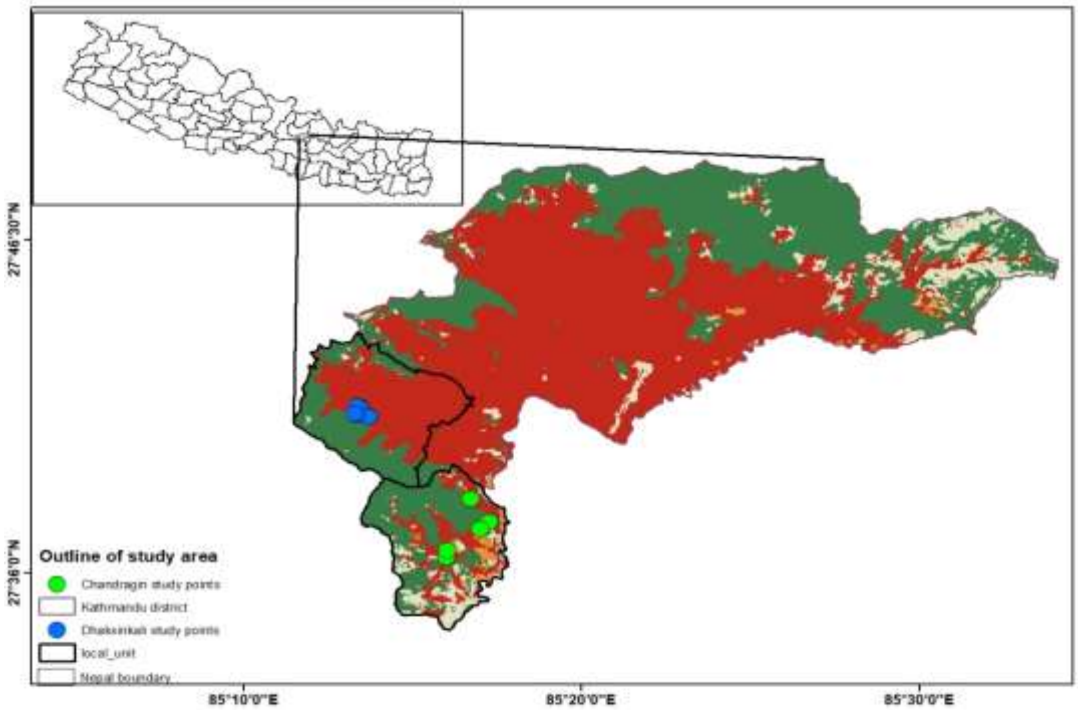

Figure 1: Location map of research site

3.2 Materials required

a. Ethylacetate
b. 70 % alcohol
c. Vials
d. Paper envelope
e. Stereoscopic microscope
f. Sweeping net
g. Cotton
h. Entomological pins
i. Entomological insect box

3.3 Method

3.3.1 Field design

A field survey was conducted in the southern part of the Kathmandu Valley, in Chandragiri and Dakshinkali areas to study pollinator visitation rates on invasive plant species. A total of 10 sites were selected, with five sites in Dakshinkali and five in Chandragiri. At each site three plots were established, resulting 15 plots in Dakshinkali and 15 plots in Chandragiri area and 30 plots in total. Within each plot, a 1m × 1 m subplot was constructed along a transect line (9 subplot in one plot). The study sites were chosen based on their high diversity of flowering plants to maximize opportunities for observing pollinators. Plots were set up at interval of 100 meters to ensure spatial independence.

Location	Site	Plot	Seasons
Chandragiri area	5	15	2
Dakshinkali area	5	15	2

Flower in the subplot were counted, with one twig considered equivalent to one flower. Pollinator insects were identified based on their interaction with the flowers, those that visited and sucked the reproductive parts of the flowers were recorded as pollinators. Insect sampling and observation were carried out for 30 minutes in each plot.

Pollinator observations were carried out by walking along fixed paths (transects) within each plot. Sampling was conducted during two distinct seasons, summer and autumn season at the same locations to account for seasonal variations. Observations and collections were carried out during periods of peak pollinator activity. Pollinators were actively searched and collected using vials containing cotton soaked in ethyl acetate, which were used to preserve specimens for later identification and analysis.

Surveys were conducted exclusively during favorable weather conditions. If there was rain or strong winds, the data collection was delayed because these weather conditions can affect pollinator activity

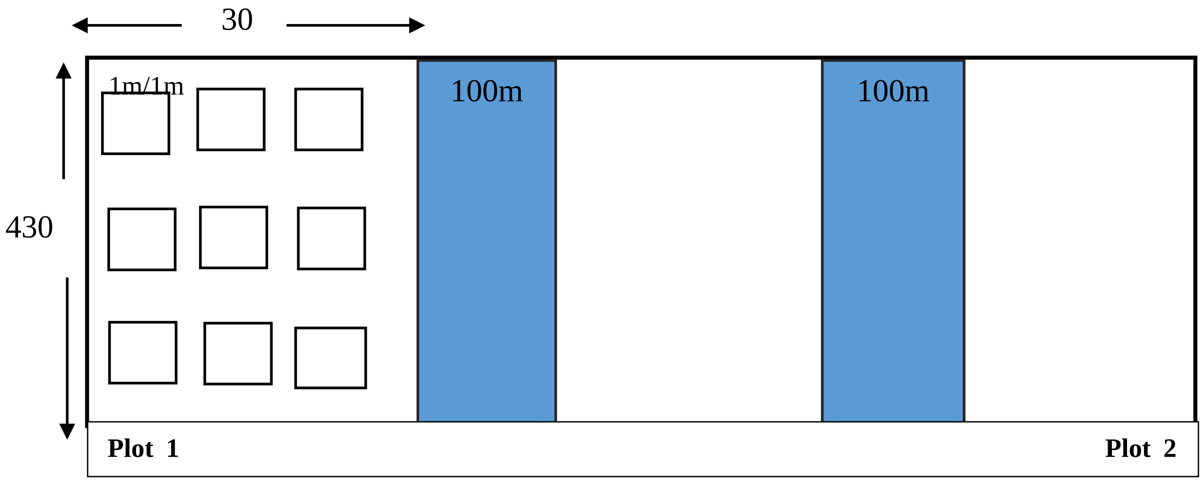

Figure 2: Site 1

3.3.2 Insect collection

a. **Sweeping net:** Insects were caught using a sweep net, which is a long-handled tool with a bag-like net used to catch insects from plants. It is mainly used to collect butterflies and other flying insects. After sweeping the net through the vegetation, a quick motion sends the insects to the bottom of the net. Holding the net in the middle keeps them from flying away Schauff, (1975).

Figure 3: Sweeping net

The pollinator were collected during June-July and November of 2024. The specimens were collected by placing them in vials and killing jars containing cotton soaked in ethyl acetate for preservation. Butterflies were handled separately and stored in tracing paper envelopes for dry preservation. Each specimen was carefully labeled with essential information, including the site name, plot name, date and time of collection, the plant species from which they were collected. Specimens were later sorted and identified based on their morphological characteristics

For the identification of pollinator, following ecological parameter were collected during the field visit.

i. Local temperature (°C)
ii. GPS point of each sites of pollinator collected

3.3.4 Preservation and species identification

The specimens collected were taken to the Central Department of Zoology's Entomology Laboratory, for detailed study. Specimens were sorted based on similar morphological characters and pinned on the entomological box. The naphthalene balls were added as preservative. The specimens were observed using a stereoscopic microscope and documented through photography. Identification was carried out up to the family level using family keys (Triplehorn & Jhonson, 2005). Further identification up to the genus level of the vespidae and syphridae was carried out using relevant taxonomic keys (Carpenter & Nguyen, 2003; Láska et al., 2013). Bumblebees were identified following the key by (Williams et al., 2010). The butterfly was identified by using the taxonomic keys provided by (Askew & Stafford, 2014; Chalise, 2010; Tangi et al., 2016). The specimen gathered during the study were preserved at the Central Department of Zoology, Tribhuvan University, for further examination. While preserving specimens were properly labeled with detailed taxonomic information, including the species name, date of collection, place of collection, and the name of the collector.

3.4 Data analysis

The collected data were compiled and organized using Microsoft Excel. Insect pollinators were categorized into major taxonomic groups (e.g., bees, butterflies, flies) based on morphological characteristics. The frequency of pollinator visits was calculated for each invasive plant species and compared between seasons (summer and autumn). Species diversity is calculated using Shannon Diversity Index (H'), Simpson index was also calculated. Regression analysis (Zero inflated regression with poison distribution) was also done to assess the relationship between insect pollinator and invasive plant abundance.

The status of recorded Pollinators were categorized into four categories; 1-2 abundance-Very Rare, 3-10 abundance- Rare, 11-30 abundance-Fairly Common and 30< abundance-Common (Shrestha et al., 2018)

3.5 Specimen deposition

The collected specimens were preserved and deposited in the museum of the Central Department of Zoology, Tribhuvan University, for future reference and research purposes.

4. Results

4.1 Proportion of pollinator visits to invasive plant during summer season

During summer season, Pollinator shows highest visitation frequency to *Lantana camara* (33.14%), followed by *Bidens pilosa* (23.54%). *Apis cerana* was the most dominant visitor, especially abundant on *Bidens pilosa*, while *Bombus* and *Amegilla* were primarily associated with *Lantana camara*. Other invasive plant such as *Parthenium hysterophorus* (11.46%), *Ageratum houstoniaum* (6.26%) received moderately visits. While *Oxalis latifolia, Ipomea carnea, Alternanthera philoxeroides* had very low visitation rate i.e. less than 1% (Table 1.)

Table 1: Proportion of pollinator individual visits to invasive plant species during summer season

Pollinators	***Lantana camara***	***Bidens pilosa***	***Parthenium hysterophorous***	***Ageratum houstoniaum***	***Oxalis latifolia***	***Ipomea carnea***	***Alternanthera philoxeroides***
Apis cerana	1.85%	7.01%	1.11%	3.69%	0.74%	0.36%	-
Bombus spp.	9.22%	-	-	-	-	-	-
Amegilla spp.	5.54%	2.95%	-	-	-	-	-
Polistes spp.	1.11%	2.95%	3.96%	-	-	-	-
Parapolybia spp.	2.21%	0.36%	-	-	0.36%	-	-
Nomioides spp.	-	1.11%	1.85%	-	-	-	0.36%
Sceliphron spp.	-	0.36%	-	-	0.36%	-	-
Syntomoides imaon	2.21%	1.85%	0.74%	-	-	-	-
Aglais caschmirensis	1.48%	-	-	0.36%	-	-	-
Acraea issoria	-	-	-	1.11%	-	-	-
Junonia iphita	1.11%	-	-	-	-	-	-

Athyma jina	0.36%	0.36%	-	-	-	-	-
Euploea core	0.36%	-	-	-	-	-	-
Pieris canidia	0.36%	0.36%	-	-	-	-	-
Catopsilia pomona	0.36%	-	-	-	-	-	-
Graphium agamemnon	1.11%	-	-	-	-	-	-
Graphium cloanthus	0.36%	-	-	-	-	-	-
Papilio polytes	0.36%	-	-	-	-	-	-
Macroglossum belis	0.36%	-	-	-	-	-	-
Pelopidas mathias	1.11%	-	-	-	-	-	-
Ancistroides folus	0.36%	-	-	-	-	-	-
Episteme adulatix	0.36%	-	-	-	-	-	-
Eristalinus spp.	0.74%	0.36%	0.74%	-	-	-	-
Episyrphus spp.	1.11%	4.43%	1.11%	0.74%	-	-	-
Melanostoma spp.	-	0.36%	0.74%	-	-	-	-
Eristalis spp.	0.74%	0.36%	0.74%	-	-	-	-
Eupodes spp.	-	0.36%	-	0.36%	-	-	-
Unidentified spp.	0.36%	0.36%	0.74%	-	-	-	-
Total	**33.14%**	**23.54%**	**11.46%**	**6.26%**	**1.82%**	**0.36%**	**0.36%**

4.2 Proportion of pollinator visits to invasive plant during autumn season

In autumn season, *Bidens pilosa* became the most visited invasive plant with nearly 20% of total visitation. While *Lantana camara* dropped sharply to 1.46% (Table 2.)

Table 2: Proportion of pollinator individual visits to invasive plant species during autumn season

Pollinators	***Lantana camara***	***Bidens pilosa***	***Ageratum houstoniaum***	***Xanthium strumarium***
Apis cerana	-	18.08%	0.36%	0.36%
Bombus spp.	0.36%	-	-	-
Eurems hecabe	-	0.74%	0.36%	-
Pieris canidia	0.74%	1.11%	0.36%	-
Pelopidas mathias	0.36%	1.85%	-	-
Total	**1.46%**	**19.93%**	**1.08%**	**0.36%**

4.3 Diversity of pollinator visiting invasive plant

The results show a clear seasonal variation in insect pollinator diversity between summer and autumn. During summer, *Lantana camara* exhibited the highest pollinator diversity (H′ = 2.55) and species richness (90), followed by *Bidens pilosa* and *Parthenium hysterophorus*. In autumn, overall diversity declined sharply, with *Lantana camara* (H′ = 1.04) and *Bidens pilosa* (H′ = 0.37) still receiving some pollinator visits. *Ageratum houstonianum* maintained relatively consistent diversity across seasons. Other species like *Ipomoea carnea*, *Alternanthera philoxeroides*, and *Xanthium strumarium* had minimal visitation, with only a single pollinator recorded.

Table 3: Diversity of Pollinator visiting invasive plant in summer and autumn season

Invasive plant	**Summer Season**			**Autumn Season**		
	Shannon(H')	**Simpson(D)**	**Richness**	**Shannon (H')**	**Simpson (D)**	**Richness**
Lantana camara	2.55	0.88	90	1.04	0.83	4
Bidens pilosa	2.12	0.85	64	0.37	0.18	54
Parthenium hysterophorus	2.00	0.86	31	-	-	-
Ageratum houstoniaum	1.20	0.64	17	1.10	1	3

Oxalis latifolia	1.33	0.76	5	-	-	-
Ipomoea carnea	0 (only one individual)	0 (only one individual)	1	-	-	-
Alternanthera philoxeroides	0 (only one individual)	0 (only one individual)	1	-	-	-
Xanthium strumarium	-		-	0 (only one individual)	0 (only one individual)	1

4.4 Number of individual of pollinators visiting invasive plant

The collected pollinators were identified into 29 morpho-species belonging to twelve different families. Among these, 17 were identified up to species level, 11 up to genus level and one up to the subfamily level. A specimen from the Vespidae family, subfamily Eumeninae, could not be identified further and this specimen is listed as Unidentified spp.

Pollinators observed on the invasive plant *Lantana camara* showed moderate shift, with a Shannon-Wiener Index (H') value of 2.55. *Apis cerena* was found to be most abundant during the study period which was made up 33.58% (n=91) which is followed by *Bombus* spp. with 9.59% (n=26) and *Amegilla* spp. is third abundant with 8.86% (n=24). Similarly, *Polistes* spp*.*, *Epysyrphus* spp*.*, *Syntomoides imaon* is made with 7.75% (n=21), 7.38% (n=20), 4.79% (n=13) respectively. Furthermore, *Nomioides* spp. comprise 3.32% (n=9) and *Parapolybia* spp., and *pieris canidia* were made up with 2.95% (n=8). Also, *Eristalis* spp., *Eristalinus* spp., and *Algalis caschmirensis* were made up with 1.85% (n=5) and *Pelopidas mathias* with 1.48% (n=4). *Melanostoma, Graphium Agamemnon, Acraea issoria, Junonia iphita, Eurems hecabe hecabe* were made up with 1.11% (n=3). *Sceliphron* spp., *Athyma jina*, *Eupeods* spp., were made up with 0.54% (n=2). Similarly, *Macroglossum belis, Episteme adulatix, Ancistroides folus, Euploea core, Catopsilia Pomona, Graphium cloanthus, Papilio polytes* Were found to be least abundant in the study area with 0.37% (n=1).

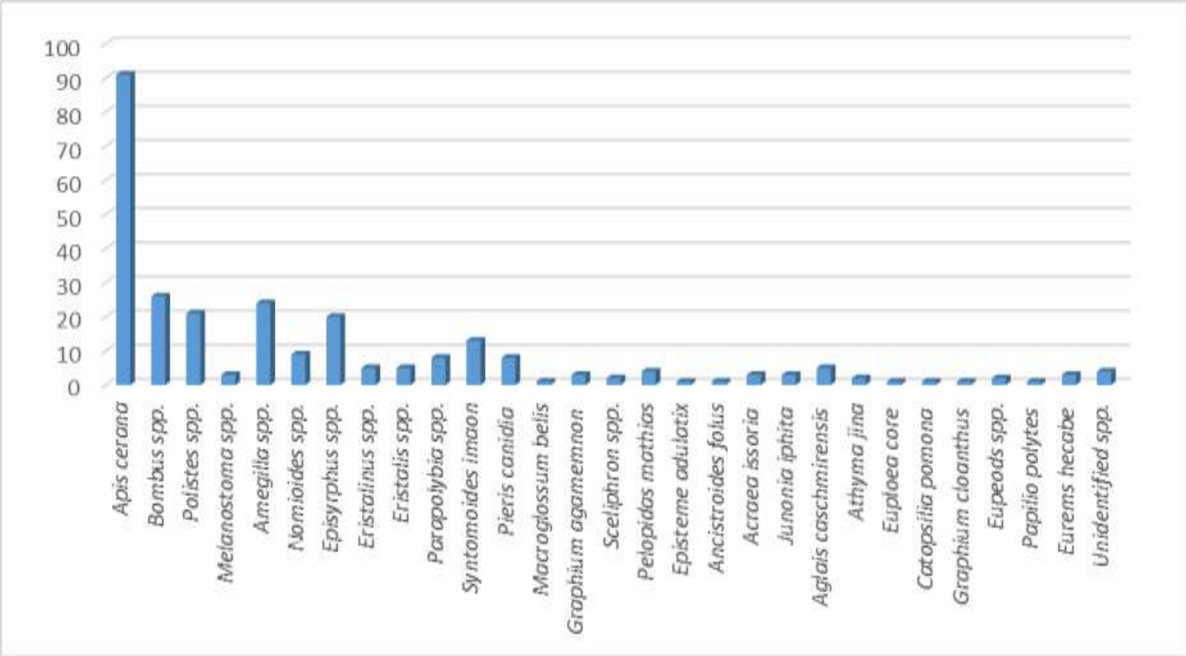

Figure 4: Cumulative number of Pollinator visiting invasive plant

4.5 Categorization of insect Pollinators of invasive plant species

During the study, *Apis cerana* was recorded as the most common pollinator species. *Bombus spp.*, *Amegilla spp.*, *Polistes spp.*, *Syntomoides imaon*, and *Episyrphus spp.* were found to be fairly common. Similarly, species such as *Parapolybia spp.*, *Nomioides spp.*, *Pieris canidia*, and *Eristalis spp.* were categorized as rare. Very few individuals of species like *Euploea core*, *Papilio polytes*, and *Graphium cloanthus* were observed, making them very rare in the study sites.

Table 4: Status of Pollinators in invasive plant Species

S.N.	Pollinators	Abundance	Status			
			Common	Fairly common	Rare	Very rare
1.	*Apis cerana*	91	–			
2.	*Bombus* spp.	26		–		
3.	*Amegilla* spp.	24		–		
4.	*Polistes* spp.	21		–		
5.	*Parapolybia* spp.	8			–	
6.	*Nomioides* spp.	9			–	
7.	*Sceliphron* spp.	2				–
8.	*Syntomoides imaon*	13		–		
9.	*Aglais caschmirensis*	5			–	
10.	*Acraea issoria*	3			–	
11.	*Junonia iphita*	3			–	
12.	*Athyma jina*	2				–
13.	*Euploea core*	1				–
14.	*Pieris canidia*	8			–	
15.	*Catopsilia Pomona*	1				–
16.	*Eurems hecabe*	3			–	
17.	*Graphium agamemnon*	3			–	
18.	*Graphium cloanthus*	1				–
19.	*Papilio polytes*	1				–
20.	*Macroglossum belis*	1				–
21.	*Pelopidas mathias*	4			–	
22.	*Ancistroides folus*	1				–
23.	*Episteme adulatix*	1				–
24.	*Eristalinus* spp.	5			–	
25.	*Episyrphus* spp.	20		–		
26.	*Melanostoma* spp.	3			–	
27.	*Eristalis* spp.	5			–	
28.	*Eupodes* spp.	2				–
29.	Unidentified spp.	4			–	

4.6 Percentage of pollinator family visiting invasive plants

Out of the total 271 individual observations, *Bidens pilosa* recorded the highest pollinator visitation (28.04%), predominantly by members of the Apidae family. This was followed by *Lantana camara* (16.98%), which attracted a diverse range of pollinators, including bees, flies, and butterflies. Syrphid flies showed a notable preference for *Bidens pilosa* (5.91%), while *Parthenium hysterophorous* received moderate visitation from both Vespidae (4.43%) and Syrphidae (3.33%). Butterfly families such as Nymphalidae and Pieridae were primarily associated with *Lantana camara*, contributing up to 3.33% of total visits which is shown in Table 4.

Table 5: Percentage of pollinator family visiting invasive plants

S.N	Order	Family	Name of Invasive plant	Pollinators (%)
1.	Hymenoptera	Apidae	*Parthenium hysterophorous*	1.11
			Lantana camara	16.98
			Bidens pilosa	28.04
			Oxalis latifolia	1.11
			Ipomea carnea	0.37
			Ageratum houstoniaum	4.06
		Vespidae	*Lantana camara*	3.69
			Bidens pilosa	3.69
			Oxalis latifolia	0.37
			Parthenium hysterophorous	4.43
		Halictidae	*Parthenium hysterophorous*	1.85
			Bidens pilosa	1.11
			Alternanthera philoxeroides	0.37
		Sphecidae	*Bidens pilosa*	0.37
			Oxalis latifolia	0.37
2.	Lepidoptera	Nymphalidae	*Lantana camara*	3.33
			Ageratum houstoniaum	1.48
			Bidens pilosa	0.37
		Pieridae	*Lantana camara*	1.48
			Ageratum houstoniaum	0.74

			Bidens pilosa	2.22
		Papilionidae	*Lantana camara*	1.85
		Hesperiidae	*Lantana camara*	1.85
		Noctuidae	*Lantana camara*	0.37
		Sphingidae	*Lantana camara*	0.37
		Erebidae	*Parthenium hysterophorous*	0.74
			Bidens pilosa	1.85
			Lantana camara	2.21
3.	Diptera	Syrphidae	*Parthenium hysterophorous*	3.33
			Bidens pilosa	5.91
			Lantana camara	2.59
			Ageratum houstoniaum	1.11

4.7 Seasonal variation of pollinator visiting invasive plant species

Various insect species visiting the flowers of invasive plants were collected and identified. A total of 29 pollinator species were recorded, representing twelve families across three insect orders. Out of these, seven species belonged to order Hymenoptera, 15 species to Lepidoptera, and five to Diptera. The entire set of identified Pollinators are as shown in Table 1.

Table 6: Seasonal variation of pollinator visiting invasive plant species

S.N	Name of pollinator	Summer	Winter	Name of invasive plants
1.	*Apis cerana*	+	+	*Parthenium, Bidens pilosa, Lantana camara, Oxalis, Agratum, Ipomea, Xanthum*
2.	*Bombus* spp.	+	+	*Lantana camara*
3.	*Amegilla* spp.	+	-	*Lantana camara, Bidens Pilosa, Oxalis*
4.	*Polistes* spp.	+	-	*Parthenium, Lantana camara, Bidens pilosa*
5.	*Parapolybia* spp.	+	-	*Lantana camara, Bidens pilosa, Oxalis*
6.	*Nomioides* spp.	+	-	*Parthenium, Bidens pilosa, Alternanthera*
7.	*Sceliphron* spp.	+	-	*Bidens pilosa, Oxalis*
8.	*Syntomoides imaon*	+	-	*Parthenium, Bidens pilosa, Lantana camara*
9.	*Aglais caschmirensis*	+	-	*Lantana camara, Agratum*

10	*Acraea issoria*	+	-	*Agratum*
11.	*Junonia iphita*	+	-	*Lantana camara*
12.	*Athyma jina*	+	-	*Bidens pilosa, Lantana camara*
13.	*Euploea core*	+	-	*Lantana camara*
14.	*Pieris canidia*	+	+	*Lantana camara, Bidens pilosa, Agratum*
15.	*Catopsilia Pomona*	+	-	*Lantana camara*
16.	*Eurems hecabe*	-	+	*Bidens pilosa, Agratum*
17.	*Graphium agamemnon*	+	-	*Lantana camara*
18.	*Graphium cloanthus*	+	-	*Lantana camara*
19.	*Papilio polytes*	+	-	*Lantana camara*
20.	*Macroglossum belis*	+	-	*Lantana camara*
21.	*Pelopidas mathias*	+	+	*Lantana camara*
22.	*Ancistroides folus*	+	-	*Lantana camara*
23.	*Episteme adulatix*	+	-	*Lantana camara*
24.	*Eristalinus* spp.	+	-	*Parthenium, Bidens pilosa, Lantana camara,*
25.	*Episyrphus* spp.	+	-	*Parthenium, Bidens pilosa, Lantana camara, Agratum*
26.	*Melanostoma* spp.	+	-	*Parthenium, Bidens pilosa,*
27.	*Eristalis* spp.	+	-	*Parthenium, Bidens pilosa, Lantana camara,*
28.	*Eupodes* spp.	+	-	*Bidens pilosa, Agratum*
29.	Unidentified spp.	+	-	*Parthenium, Bidens pilosa, Lantana camara*

4.8 Regression analysis between Pollinator and invasive plant abundance

We fitted a Poisson regression model to examine with pollinator abundance as the dependent variable and invasive plant abundance as the predictor. How invasive plant abundance affects pollinator abundance. The analysis showed a significant positive effect of invasive plants on pollinators (Estimate = 0.037 ± 0.0067 SE, $z = 5.56$, $p < 0.001$).each additional invasive plant was linked to about 3.8% rise in pollinator ($\exp(0.037) \approx 1.038$). The intercept was negative (Estimate = –0.727, $p < 0.001$), suggests that in the absence of invasive plants, pollinator abundance was predicted to be very low (~0.5 individuals).

However, the model suggests that (McFadden's pseudo-R^2 = 0.044) invasive plant abundance explains about 4.4% of the variation in pollinator counts.

Table 7: Regression analysis between Pollinator and invasive plant abundance

	Coefficients	Standard error	Z value	P-value
Intercept	-0.73	0.12	-6.10	< 0.001
Invasive plant density	0.04	0.01	5.56	<0.002

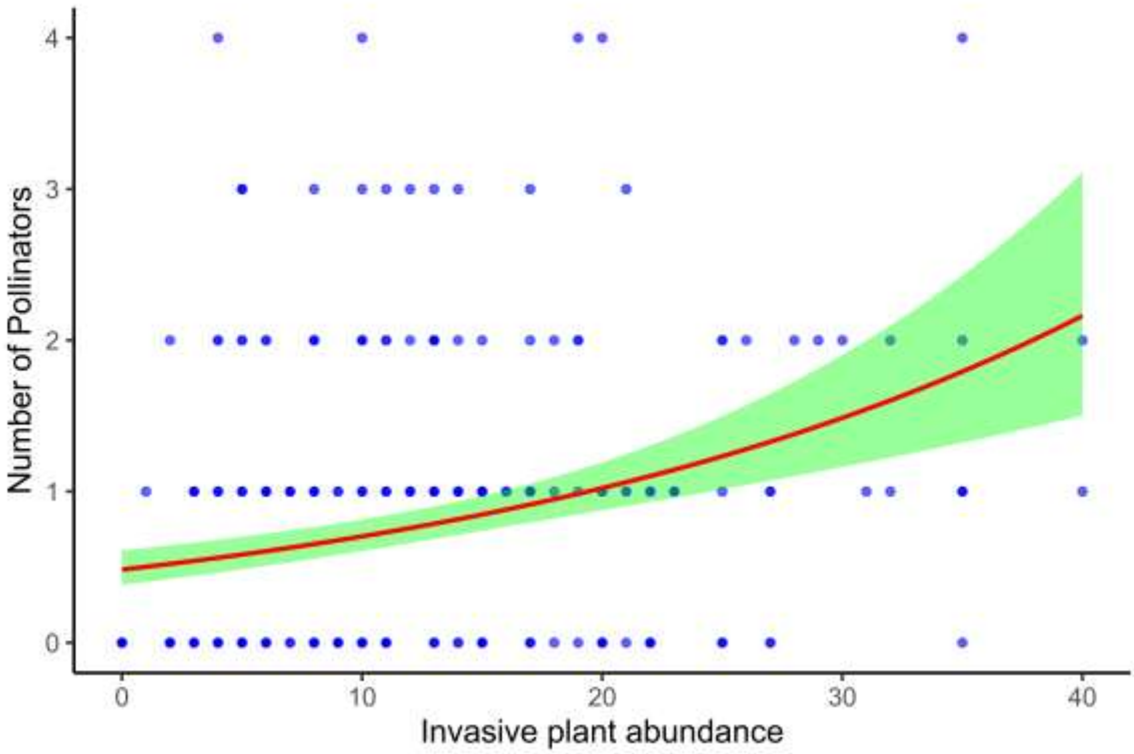

Figure 5: Relation between pollinator and invasive plant abundance

5. Discussion

5.1 Diversity of invasive plant

This study revealed a rich diversity of insect pollinators visiting invasive plant species across the southern Kathmandu Valley, with a total of 28 pollinator species recorded during summer and 5 during autumn season. The dominant orders were Hymenoptera, Lepidoptera, and Diptera, consistent with previous studies (Stout & Tiedeken, 2017), which also found these orders to be among the most frequent floral visitors in invaded ecosystems.

Pollinator richness was much higher in the summer season, likely due to warmer temperatures, increased floral availability, and greater insect activity (Kudo & Ida, 2013). During autumn, floral resources were limited to a few invasive plants like *Bidens pilosa* and *Lantana camara*, which still managed to attract pollinator species. This highlights the potential role of some invasive plants in maintaining pollinator resources during resource-scarce periods (Bartomeus et al., 2008). This is supporting the hypothesis proposed by (Bjerknes et al., 2007) that invasive species may have a positive impact on pollinator populations as a result of an increase in landscape-level resource availability (Tepedino et al., 2008). However, this may also disrupt natural seasonal dynamics and affect native plant-pollinator.

Hymenoptera dominated the pollinator community, especially *Apis cerana*, which was categorized as very common based on visitation frequency. This aligns with similar studies across South Asia, where *A. cerana* has been identified as a generalist pollinator with strong associations to both native and invasive flora (Stewart et al., 2018). Lepidopterans were the second most abundant group, with many species in the Nymphalidae and Papilionidae families, especially on Verbenaceae species. A study by (Baboo et al., 2019) found 26 species of pollinator in the *Lantana camara*. Of which *Amegilla zonata* from hymenoptera and Butterflies Species belonging to Family Papilionidae, Nymphalidae and Hesperidae were the most frequent Pollinator. Dipterans, particularly syrphid flies, though less abundant, were important visitors to Asteraceae plants such as *Bidens pilosa* and *Ageratum* similar to findings by (Hanula & Horn, 2011), who highlighted syrphids as key but often overlooked pollinators in disturbed habitats.

The invasive plant *Lantana camara* attracted the widest range of pollinators, particularly *Bombus* spp., *Amegilla* spp., and *Syntomoides imaon*. This likely results from its brightly colored flowers, long blooming period, and rich nectar rewards traits known to enhance pollinator attraction (Sharma et al., 2005). The study conducted by (Baboo et al., 2019), (Milne, 2016), and (Mukherjee et al., 2022) consistently report that *Lantana camara* attracts a wide range of visitors, including bees, butterflies, and thrips, with members of the families Papilionidae, Nymphalidae, and Hesperiidae among the most frequent butterfly visitors. (Mukherjee et al., 2022) further demonstrated a positive relationship between *Lantana* abundance, butterfly species richness, and numbers, indicating that this invasive plant may provide consistent floral resources for pollinators. Likewise, species such as *Bidens pilosa, Ageratum houstonianum,* and *Parthenium,* characterized by their composite inflorescences and accessible nectar, received frequent visits from pollinators. These findings are in agreement with (Chrobock et al., 2013), who reported that floral morphology and accessibility in invasive Asteraceae can promote high visitation. In contrast, *Ipomoea carnea***,** *Alternanthera philoxeroides***,** *and Xanthium strumarium* had very low pollinator diversity (H′ = 0), with only a few or no pollinators recorded. This could be attributed to factors such as limited nectar production, floral morphology unsuited for local pollinators, or their seasonal phenology. Studies like (Moroń et al., 2009) have emphasized that invasive plant traits significantly influence their attractiveness to pollinators.

The findings emphasize the ecological significance of certain invasive plants, such as *Lantana camara* and *Bidens pilosa*, in sustaining pollinator populations during periods of floral scarcity. Although invasive plants can support pollinators, especially during winter when other flowers are scarce, they may also cause problems. These invasive species may divert pollinators from native flora, potentially decreasing pollination rates among native plants (Bjerknes et al., 2007). So, a balanced approach is needed to manage invasive plant species while promoting native flora.

5.2 Seasonal variation in pollinators

The study explored higher diversity of pollinator number in summer seasons in comparison with the autumn season. A total of 209 individuals of pollinator were found in the summer while only 62 individuals of pollinators were found during autumn seasons (more than one third of pollinator). This shows that warm weather and more flowers in summer support higher pollinator activity. The absence of Diptera (flies) in autumn and their dominance in summer suggests a strong seasonal sensitivity among some pollinator groups. Warmer summer temperatures likely promote higher metabolic rates and greater flower availability, which attract a wider range of pollinators. In contrast, autumn season limit both floral resources and insect activity, reducing pollinator visitation rates. Supporting this, (Harris et al., 2024) reviewed 18 studies, mostly using honeybees as indicators in northwest Europe and found that floral resource availability varies seasonally. Their results showed that spring and early summer, especially April, are generally the most favorable periods for pollinator foraging, while late summer and autumn, particularly August, tend to have fewer available floral resources.

Our result showed a significant positive relation between pollinator and invasive plant abundance. This suggests that denser flowering by invasives can attract more pollinators, likely through increased nectar and pollen availability. This aligns with the findings of (Bjerknes et al., 2007), which suggest that a high density of flowers and trait similarity can increase pollinator visits to invasive species, possibly leading to a decline in native plant pollination due to pollinator preference for the invasives.

6. Conclusion and recommendation

This study, conducted in the southern part of the Kathmandu Valley, revealed the vital role insect pollinators play in the reproduction of invasive plant species. Hymenopteran pollinators, especially *Apis cerana*, was found to be dominant across seasons, with invasive plants like *Lantana camara* and *Bidens pilosa* serving as key floral resources due to their long flowering periods and nectar abundance. Although invasive species can threaten native biodiversity by competing with native flora, they also support pollinators by providing alternative foraging resources. They may also provide vital foraging resources for pollinators, especially when native floral resources are scarce. To support pollinator conservation and sustainable pollination services, it is essential to manage invasive species while promoting native plants. Protecting habitats of year round of pollinators like *Apis cerana* and understanding seasonal shifts in pollinator activity such as the autumn absence of Diptera should be explored. A balanced strategy integrating habitat restoration, pollinator protection, and invasive plant control is necessary to maintain ecological stability and pollination effectiveness.

6.1 Recommendation

Based on the results of this study following recommendations have been made:

- Studying all invasive plant species in Kathmandu Valley is important to understand the diversity of their pollinators.
- All the seasons was also necessary to analyze the seasonal variation among pollinators of invasive plant.

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Appendices

Table 8: List of Insect pollinator visiting invasive plant species during summer season

S.N	Scientific name of pollinator	Order	Family	Invasive plant family	Invasive plant
1.	*Apis cerana*	Hymenoptera	Apidae	Asteraceae, Verbenaneae, Oxalidae	*Parthenium, Bidens pilosa, Lantana camara,Oxalis, Agratum, Ipomea*
2.	*Bombus* spp.	Hymenoptera	Apidae	Verbenanceae	*Lantana camara*
3.	*Amegilla* spp.	Hymenoptera	Apidae	Asteraceae, verbenaceae, oxalidae	*Bidens pilosa, Lantana camara,Oxalis*
3	*Polistes* spp.	Hymenoptera	Vespidae	Asteraceae, Verbenaneae	*Parthenium, Bidens pilosa, Lantana camara*
5.	*Parapolybia* spp.	Hymenoptera	Vespidae	Asteraceae, verbenaceae, oxalidae	*Lantana camara, Bidens pilosa, Oxalis*
6.	*Nomioides* spp.	Hymenoptera	Halictidae	Asteraceae, Amaranthaceae	*Parthenium, Bidens pilosa, Alternanthera*
7.	*Sceliphron* spp.	Hymenoptera	Sphecidae	Asteraceae, Oxalidaeae	*Bidens pilosa, Oxalis*
8.	*Syntomoides imaon*	Lepidoptera	Erebidae	Asteraceae, verbenaceae	*Parthenium, Bidens pilosa, Lantana camara*
9.	*Aglais caschmirensis*	Lepidoptera	Nymphalidae	Verbenaceae, Asteraceae	*Lantana camara, Agratum*
10	*Acraea issoria*	Lepidoptera	Nymphalidae	Asteraceae	*Agratum*
11.	*Junonia iphita*	Lepidoptera	Nymphalidae	Verbenaceae	*Lantana camara*
12.	*Athyma jina*	Lepidoptera	Nymphalidae	Asteraceae, Verbenaceae	*Bidens pilosa, Lantana camara*
13.	*Euploea core*	Lepidoptera	Nymphalidae	Verbenaceae	*Lantana camara*
14.	*Pieris canidia*	Lepidoptera	Pieridae	Asteraceae	*Lantana camara, Bidens pilosa*
15.	*Catopsilia Pomona*	Lepidoptera	Pieridae	Verbenaceae	*Lantana camara*
16.	*Graphium agamemnon*	Lepidoptera	Papilionidae	Verbenaceae	*Lantana camara*
17.	*Graphium cloanthus*	Lepidoptera	Papilionidae	Verbenaceae	*Lantana camara*
18.	*Papilio polytes*	Lepidoptera	Papilionidae	Verbenaceae	*Lantana camara*

19.	*Macroglossum belis*	Lepidoptera	Sphingidae	Verbenaceae	*Lantana camara*
20.	*Pelopidas mathias*	Lepidoptera	Hesperiidae	Verbenaceae	*Lantana camara*
21.	*Ancistroides folus*	Lepidoptera	Hesperiidae	Verbenanceae	*Lantana camara*
22.	*Episteme adulatix*	Lepidoptera	Noctuidae	Verbenanceae	*Lantana camara*
23.	*Eristalinus* spp.	Diptera	Syphridae	Asteraceae, verbenaceae	*Parthenium, Bidens pilosa, Lantana camara*
24.	*Episyrphus* spp.	Diptera	Syphridae	Asteraceae, Verbenanceae	*Parthenium, Bidens pilosa, Lantana camara, Agratum*
25.	*Melanostoma* spp.	Diptera	Syphridae	Asteraceae,	*Parthenium, Bidens pilosa*
26.	*Eristalis* spp.	Diptera	Syphridae	Asteraceae, Verbenaceae	*Parthenium, Bidens pilosa, Lantana camara*
27.	*Eupodes* spp.	Diptera	Syphridae	Asteraceae	*Bidens pilosa, Agratum*
28.	*Unidentified* spp.		Vespidae	Asteraceae	*Parthenium, Bidens pilosa, Agratum*

Table 9: List of Insect pollinator visiting invasive plant species during autumn season

S.N	**Name of pollinator**	**Order**	**Family**	**Invasive plant family**	**Invasive plant**
1.	*Apis cerana*	Hymenoptera	Apidae	Asteraceae	*Bidens pilosa, Xanthium, Agratum*
2.	*Bombus* spp.	Hymenoptera	Apidae	Verbenaceae	*Lantana camara*
3.	*Eurems hecabe*	Lepidoptera	Pieridae	Asteraceae	*Bidens pilosa, Agratum*
4.	*Pieris canidia*	Lepidoptera	Pieridae	Asteraceae, verbenaceae	*Lantana camara, Bidens pilosa, Agratum*
5.	*Pelopidas mathias*	Lepidoptera	Hesperiidae	Verbenaceae	*Lantana camara*

Table 10: Pollinators of invasive plant in both the seasons (summer and autumn)

Pollinator	**Summer**	**Winter**
Apis cerana	40	51
Bombus spp.	25	1
Amegilla spp.	24	-
Polistes spp.	21	-
Parapolybia spp.	8	-
Nomioides spp.	9	-
Sceliphron spp.	2	-
Syntomoides imaon	13	-
Aglais caschmirensis	5	-
Acraea issoria	3	-
Junonia iphita	3	-
Athyma jina	2	-
Euploea core	1	-
Pieris canidia	2	6
Catopsilia Pomona	1	-
Eurems hecabe	-	3
Graphium agamemnon	3	-
Graphium cloanthus	1	-
Papilio polytes Romulus	1	-
Macroglossum belis	1	-
Pelopidas mathias	3	1
Ancistroides folus	1	-
Episteme adulatix	1	-
Eristalinus spp.	5	-
Episyrphus spp.	20	-
Melanostoma spp.	3	-
Eristalis spp.	5	-
Eupodes spp.	2	-
Unidentified spp.	4	-
Total	**209**	**62**

Annex I: Identified Insect Pollinators with Diagnostic Characters

S.N.	Taxa	Diagnostic Characters
1.	*Apis cerana*	Distal abscissa of vein-M in hind wing present; Moderate size; Abdominal terga I-III partly or completely black
2.	*Bombus* spp.	Larger than honeybee; always furry, robust; flying with deep buzz; tails are either white, red, buff or brown and some have yellow bands
3.	*Amegilla* spp.	Black abdomen with bright blue, iridescent bands; thorax is covered with brown hairs; Tan or brownish wings
4.	*Polistes* spp.	Clypeus pointed, truncate or rounded; parategula absent; claws simple; Hind wing with jugal lobe; metasoma sessile to subsessile; Metasomal segment I subsessile
5.	*Parapolybia* spp.	Clypeus pointed, truncate or rounded; parategula absent; claws simple; Hind wing with jugal lobe; metasoma sessile to subsessile; Metasomal segment I shaped differently; in dorsal view basally petiolate to long petiolate; Mesepisternum with scrobal sulcus
6.	*Nomioides* spp.	Apex of the marginal cell rounded or truncate: Metasoma with pale integument bands on base of terga; yellow integument maculations on head, metasoma and mesosoma
7.	*Sceliphron* spp.	Propodeum with U shaped dorsal enclosure defined tarsi with plantulae; Body black and yellow colour.
8.	*Syntomoides imaon*	Dark blue-black body with bright yellow marking on the I and V abdominal segment; yellow collar behind the head; In forewing one large dorsal hyaline cell extending from the wing base to the termen
9.	*Aglais caschmirensis*	Upperside of forewings bright orange with black patches and spots; Hindwings is orange with black marginal spots near the edges; underside of the wings dark brown and mottled.
10	*Acraea issoria*	Small leathery wing; antennae black; Upperside of wings are velvety black with broad orange band in the middle; white palpi, abdomen yellow-brown; underside of the wings are shining brown with changeable colors and ash tipped wings.
11.	*Junonia iphita*	Upperside of the wing is chocolate brown, often darker brown marking; the underside is darker brown, with unevenly washed out whitish scaleand darker brown fasciae (bands); Hindwing has a row of Postdiscal ocelli (eye spots).
12.	*Athyma jina*	Wingspan is about 50-60mm; wings are brownish-gray on upperside, yellowish-brown on underside.
13.	*Euploea core*	Wingspan 85-95mm; Wings are glossy black with rows of white spots on the margins
14.	*Pieris canidia*	Mostly creamy or white colours; underside and upper side of the wings with

		distinct spots; Hindwing from pale to white; Long hairs on head and thorax greenish gray; Antenna black with minute white specks; Abdomen black, beneath head and thorax and abdomen white.
15.	*Catopsilia Pomona*	Mostly with creamy, white, yellow colours; thorax clothed with long yellow or sometimes greenish hairs, sometimes greenish hairs, abdomen pale yellow
16.	*Graphium agamemnon*	Wingspan is about 80-90mm; upperside of the wing is black with bright green spots; green marking are more prominent towards the forewing base and become yellowish toward the outer margin of the hindwing; underside is pale brown with purple tinged scales and the same green spotting; dark patches and red spots on the underside of the hindwing; elongated tail on the hindwing.
17.	*Graphium cloanthus*	Wingspan is about 85-95mm; Translucent pale blue-green, tailed hindwing
18.	*Papilio polytes*	Mainly black or dark colours with conspicuous tails on hind wings; Antennal tips with knob; post-marginal area of hindwings are with distal band of elongated white spots
19.	*Macroglossum belis*	Forewings have two antemedian lines and the first and second discal lines are evenly curved; Hindwing are characterized by a prominent cadmium-yellow median band, broadly by blackish-brown at the base and distal edge; Underside of the wings is a hazel-chestnut colour, often appearing brighter than abdomen; Probosis is long and slender.
20.	*Pelopidas mathias*	Wingspan is about 32-38mm; female upper forwing with apical spots often in line, spot squarish; underside of hindwing with small spot in cell and 0 to 7 discal spots
21.	*Ancistroides folus*	Black with large white patches on hindwings and smaller white spots on forewing; underside of the wings is mostly white with brown edges and spots
22.	*Episteme adulatix*	Head and thorax black with the abdomen having blood-red bands; Forewings are black with large yellow marking, a row of white spots and at base; Hind wings black with small white submarginal spots; medial segment of abdomen is orange
23.	*Eristalinus* spp.	Face dark or yellow; Scutellum never yellow; sometimes orange brown; Wing vein R4+5 with strong dip in the cell below; Body with or without metallic bronze luster; bee like appearance; Eyes striped,
24.	*Episyrphus* spp.	Face entirely yellow; Scutellum always yellow; metafemur never with a small tooth apicoventrally; Abdomen more or less parallel sided, as broad as suctum; Abdomen with ‘double bands’ on t3 and t4.
25.	*Melanostoma* spp.	Face dark or yellow; Scutellum never yellow; sometimes orange brown; Wing vein R4+5 without strong dip in the cell below Face entirely black;Abdomen slender and parallel sided, as broad as suctum; Abdomen with clear orange marking, triangular or rectangular in t3 and t4;

26.	*Eristalis* spp.	Face dark or yellow; Scutellum never yellow, sometimes orange brown; Wing vein R4+5 with strong dip in the cell below; bee like appearance; Eyes concolorous without stripes; wing cell R1 closed.
27.	*Eupodes* spp.	Abdomen broad and oval shaped, broder than suctum; Abdomen with yellow spots on t3-t4, sometimes connected to form bands; Femora entirely yellow or partially black at the base;
28.	*Eurems hecabe*	Commonly yellow with expansive black apical and terminal area of forewings; forewings with black inner margin

Photoplates I

Photo plate 1: Hymenoptera, Apidae, A: *Amegilla* sp. B: *Apis cerana* C: *Bombus* sp. (CDZ,TU)

Photo plate 2: Lepidoptera, Pieridae, A: *Eureme hecabe*; B: *Catopsila Pomona*; C: *Pieris canidia* (CDZ,TU)

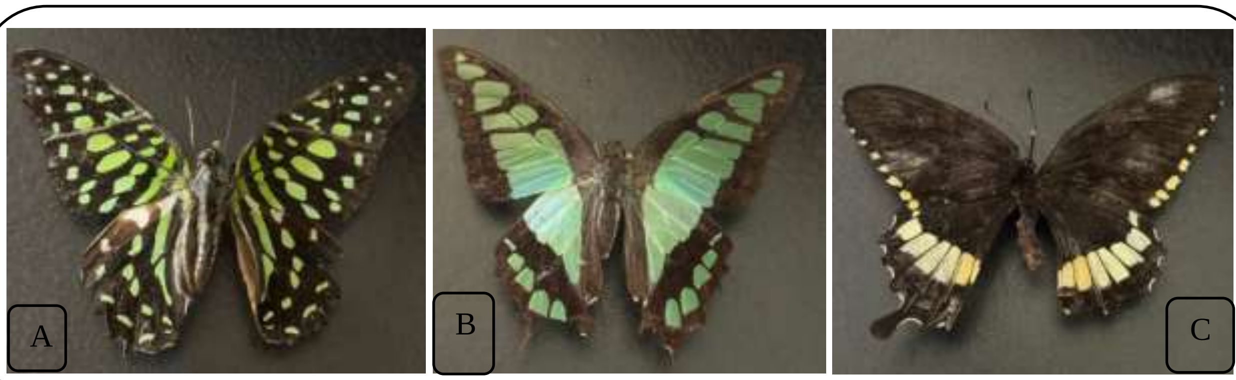

Photo plate 3: Lepidoptera, Papilionidae, A: *Graphium agamemnon*; B: *Graphium cloanthus*, C: *Papilio polytes* (CDZ, TU)

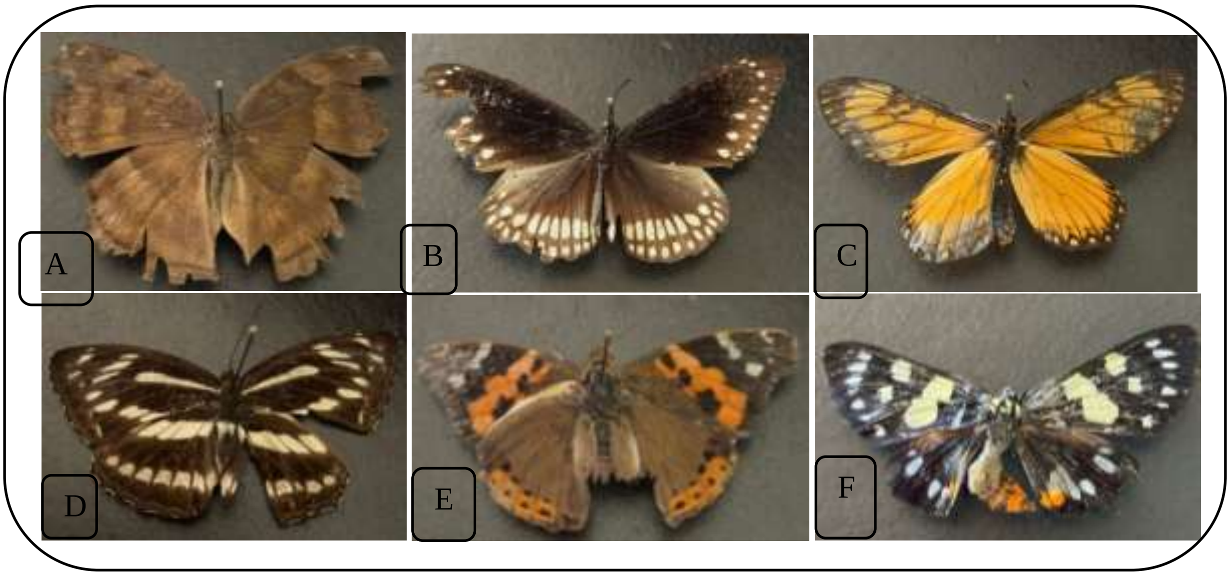

Photo plate 4: Lepidoptera, Nymphalidae, A: *Junonia iphita; B: Euploea core; C: Acraea issoria; D: Athyma jina; F: Episteme adulatix* (CDZ,TU) *E: Aglais caschmirensis; D:* Noctuidae family, *Episteme adulatix*

Photo plate 5: Lepidoptera, Hesperidae, A: *Ancistroides folus*; B:*Pelopidas mathias;* C:Lepidoptera, Erebidae, *Sytomoides imaon* (CDZ,TU)

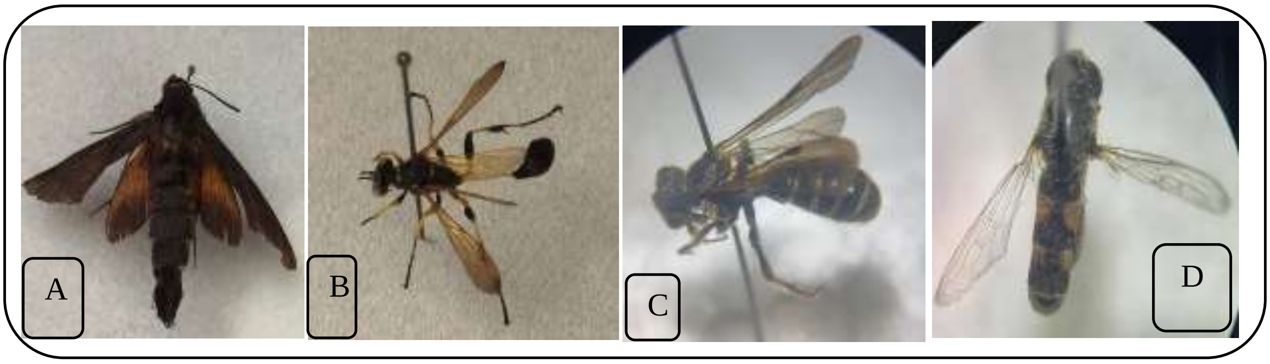

Photo plate 6: A: Lepidoptera, Sphingidae, Macroglossum belis; B:Hymenoptera, Sphecidae , *Sceliphron* sp. ; C: Hymenoptera, Halictidae, *Nomioides* sp. ; D: Diptera, Syphridae, *Melanostoma* sp. (CDZ,TU)

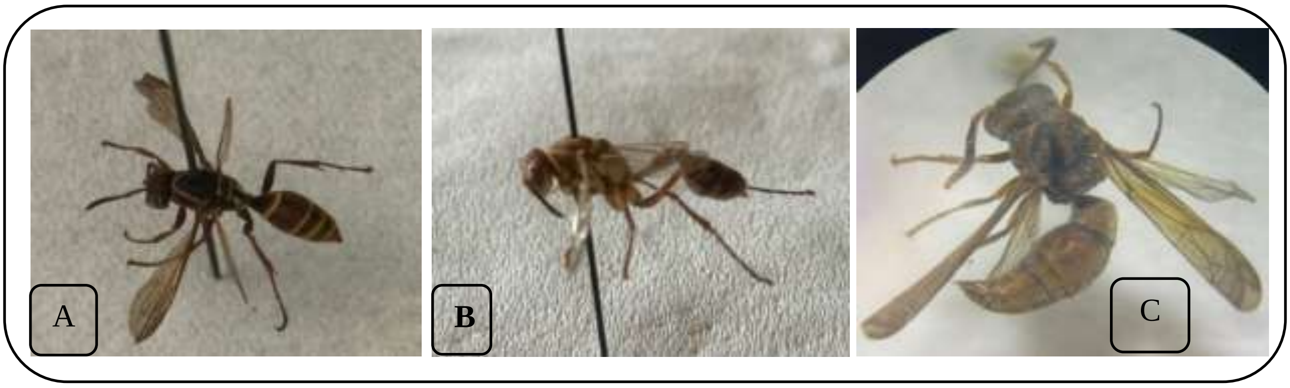

Photo plate 7: Hymenoptera, Vespidae, A: *Polistes* sp. ; B: *Parapolybia* sp. ; C: Unidentified sp.

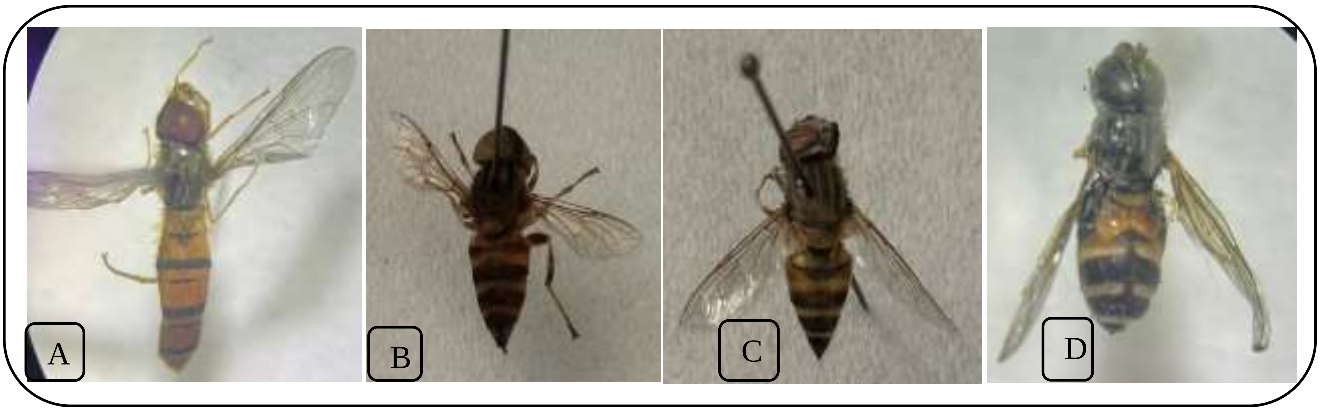

Photo plate 8: Diptera, Syphridae, A: *Episyrphus* sp. ; B: *Eristalis* sp. ; C: *Eristalinus* sp. ; D: *Eupodes* sp.

Photoplates II

Photoplate 9: Pollinators foraging invasive plant *Bidens pilosa*

Photoplate 10:.Pollinators foraging on *Ageratum houstoniaum*

Photoplate 11. Pollinators foraging on *Parthenium hysterophorous* and *Lantana camara*