Bangladesh J. Zool. ***54****(1): 01-15, 2026* ISSN: 0304-9027
eISSN: 2408-8455

TAXONOMY AND BIODIVERSITY ASSESSMENT OF WASP SPECIES ACROSS DHAKA FOCUSING ON SUBURBAN REGIONS

Anika Shithi, Nishat Tahiat Mim, Md. Towhidur Rahman and Abu Faiz Md. Aslam*

Department of Zoology, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh

Abstract: Wasps (Hymenoptera) play vital ecological roles as pollinators, predators, and natural pest regulators, yet their diversity in Bangladesh remains poorly studied. This research provides a taxonomic and biodiversity assessment of wasp species across suburban regions of Dhaka. Specimens were collected from March 2024 to February 2025 across eight suburban locations. A total of 43 species from 11 families were identified through morphological examination, and dichotomous keys were developed to aid reliable species-level identification. Community composition revealed Vespidae as the most dominant family (40%), followed by Sphecidae (27%) and Ichneumonidae (9%), while Leucospidae showed the lowest abundance (0.3%). Biodiversity indices indicated that Vespidae had the highest diversity and species richness (Shannon-Wiener Index = 2.221; Margalef Diversity Index = 2.192), whereas Scoliidae showed the least even distribution (Dominance Index = 0.271). Bipartite network analysis highlighted strong associations between wasp families and host plants, particularly Fabaceae and Asteraceae families. Seasonal heatmap analysis revealed distinct species-specific peaks, with *Polistes watti* and *P. olivaceus* most active in March and *Dielis* sp. in May, while overall activity declined from October to January. These findings provide baseline data on suburban wasp diversity in Dhaka and offer valuable insights into their taxonomy, seasonal dynamics, and ecological interactions.

Key words: Hymenoptera, Wasps, Taxonomy, Biodiversity assessment, Suburban Dhaka, Seasonal dynamics.

INTRODUCTION

Hymenoptera is among the most diverse orders of insects in the world, containing more than 150000 known species (Dowton *et al.*, 1994). Among the Hymenopterans, wasps are a paraphyletic group that includes about 103,000 currently known species (Brock *et al.*, 2021). Wasp species belong to a diverse range of families. Wasps play a vital role in pollination (Zhang, 2021) and pest control, with over 30,000 species preying on bugs and flies (Sumner, 2021).

**Author for correspondence:* <afmaslam@juniv.edu>
 DOI: https://doi.org/10.3329/bjz.v54i1.92168

Their venom has antibacterial properties (Wahed *et al.,* 2021). Wasp nests, rich in minerals, also have medicinal value, while social wasp venom shows cancer-fighting potential (Moreno *et al.,* 2015). Taxonomy and biodiversity assessment of wasp species are essential for understanding their ecological roles and informing conservation strategies. Accurate taxonomic classification facilitates the identification of new species, helping to monitor changes in biodiversity due to habitat loss, climate change, and anthropogenic activities (Foottit and Adler, 2017). Despite their importance, wasps remain understudied in many regions, creating gaps in conservation efforts (Sharkey, 2007; Wilson, 2021). Integrating taxonomy with biodiversity data helps shape effective policies to protect wasp species and support sustainable ecosystem management (LaSalle and Gauld, 1993).

Despite their ecological significance as pollinators and natural pest controllers, studies on wasp diversity and taxonomy in Bangladesh remain limited. Although molecular taxonomy exist for other hymenopterans, particularly honey bees (*Apis* spp.) (Mim *et al*., 2024), comparable studies on wasps are still scarce. While there are some local records, including studies on parasitic wasps from Chittagong (Mazumdar *et al.,* 2019, 2023) and species from university campuses in Dhaka (Akter *et al.,* 2020), a comprehensive assessment has yet to be conducted in the suburban areas of Dhaka. These rapidly changing suburban landscapes harbor wasp communities that play vital ecological roles, yet remain poorly documented. The lack of data restricts our understanding of their taxonomy, distribution, and ecological functions, highlighting the need for focused studies in these ecologically important habitats (Rahman and Aslam, 2025).

Urbanization significantly alters habitat structures, affecting insect biodiversity, including wasps (McKinney, 2002; Hall *et al.,* 2017). Suburban areas, as transitional zones between urban and rural landscapes, offer a unique mix of native and non-native vegetation, creating diverse microhabitats and acting as ecological corridors that influence species richness and distribution (Faeth *et al*., 2011; Raupp *et al.,* 2010). These rapidly changing suburban landscapes therefore harbor wasp communities that are both ecologically significant and poorly documented.

Understanding the taxonomy and biodiversity of wasp species in suburban regions is essential for documenting local insect diversity, evaluating the ecological impacts of urbanization, guiding conservation strategies, advancing scientific knowledge, and raising public awareness. In this context, the present study provides baseline data through a comprehensive taxonomic and biodiversity assessment of wasp species in suburban areas of Dhaka, contributing to our understanding of their ecological roles and supporting broader ecological research.

MATERIAL AND METHODS

Study area: The study was conducted in selected suburban regions of Dhaka, Bangladesh. These regions were chosen for their relatively low levels of urbanization compared to the city center, with more green spaces and diverse habitats that may support a higher variety of wasp species. Samples were collected from Manikganj, Gazipur, Savar, Ashuliya, Keraniganj, Demra, and Purbachal (Fig. 1).

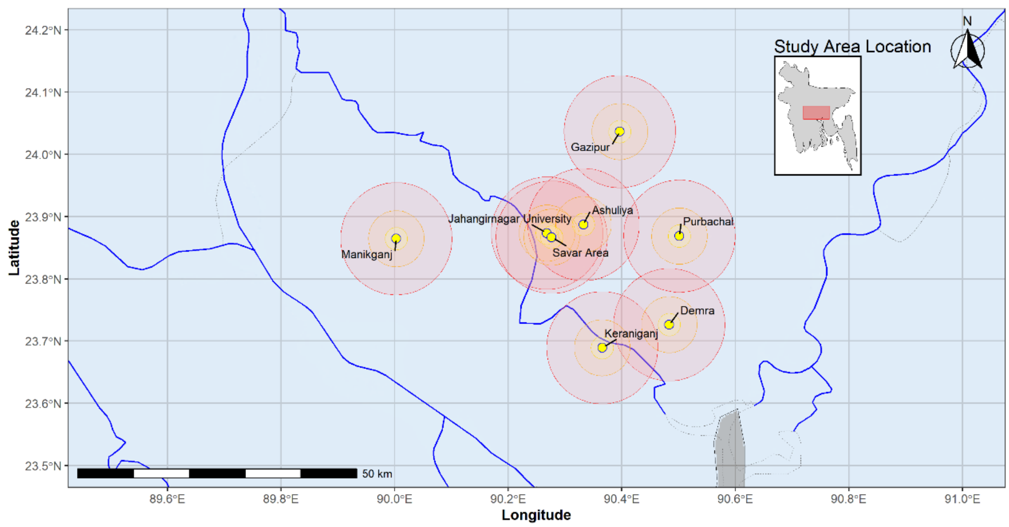

Fig. 1. Sampling area: Manikganj, Gazipur, Savar Area, Jahangirnagar University Campus, Ashuliya, Keraniganj, Demra, and Purbachal

Sampling methods: Wasps were collected by using a sweep net through vegetation, including shrubs, flowers, and trees, to capture wasps from the air and foliage. This method targeted flying and resting wasp species. Nest-building wasps were collected from or near their nests. Collections were conducted from March 2024 to February 2025. Collected samples were brought to the laboratory for further studies. A total of 1,116 specimens were studied.

Taxonomic identification: After sample collection, wasps were carefully preserved for identification. A key taxonomic approach was used for species identification based on morphological characteristics such as body size, wing venation, coloration, leg morphology, and antennal structure. In terms of species identification, the morphologically identifying keys were developed based on several studies and terminologies according to the established standards (Buck *et al.*, 2008; Gulmez and Can, 2015; Bohart and Menke, 1976).

Data analysis: A bipartite network was constructed to analyze interactions between wasp families and habitat types (plant families from where they were collected) and the nests of the wasp. One node set represented wasp families, the other habitat types, with edges indicating species presence. Edge weight was determined by species abundance (individual count) and richness (number of species per family). The network was built and analyzed in R using the igraph and bipartite packages (R Core Team, 2020). Key metrics- degree, connectance, nestedness, and modularity were calculated to assess interaction structure and habitat preferences (Pilosof *et al.,* 2017).

Heatmap analysis was used to visualize seasonal variations in wasp occurrence (Wilkinson and Friendly, 2009). A heatmap was generated in R (ggplot2/pheatmap) to represent species abundance across months.

Biodiversity metrics such as species richness, abundance, and diversity indices (e.g., Shannon-Wiener Index, Simpson's Index) were calculated to assess the species composition of wasps in the suburban areas of Dhaka. The Shannon-Wiener Index (H') (Shannon and Weaver, 1949), Pielou's Evenness Index (J') (Pielou, 1966), Margalef Diversity Index (D_{Mg}) (Margalef, 1958), Simpson's Index (D) (Simpson, 1949), and Simpson's Diversity Index (1-D) (Simpson, 1949) were calculated.

$H' = -\sum_{i=1}^{s} pi \ln pi$; where pi is the proportion of individuals of the ith species relative to the total number of individuals, and S is the total number of species

$J' = \frac{H'}{\ln S}$; where H' is the Shannon-Wiener Index, and S is the total number of species

$D_{Mg} = \frac{S-1}{\ln N}$; where S is the total number of species, and N is the total number of individuals

$D = \sum_{i=1}^{s} pi^2$; where pi is the proportion of individuals of the ith species

$1-D = 1-\sum_{i=1}^{s} pi^2$

The interpretations of the different diversity indices used in this study are summarized in Table 1.

Table 1. Representing the interpretations for different diversity indices

Indices	Range	Interpretation
Shannon-Wiener Index(H')	0 to $\ln S$	Higher values = greater diversity
Pielou's Evenness (J')	0 to 1	1= perfect evenness; undefined for single-species communities
Margalef Diversity Index (D_{Mg})	0 to ∞	Higher values = greater species richness
Simpson's Index (D)	0 to 1	1 = complete dominance; lower values = higher diversity
Simpson's Reciprocal Index (1/D)	1 to S	Higher values = greater diversity
Simpson's Diversity Index (1 - D)	0 to 1	1 = high diversity; 0 = complete dominance

Ethical considerations: All ethical guidelines for entomological studies were followed. Wasp species were handled humanely, and no endangered or protected species were harmed. The study adhered to local regulations on biodiversity conservation and environmental protection.

RESULTS AND DISCUSSION

A total of 43 wasp species belonging to 11 families were identified from the study area. Morphological examination of diagnostic characters allowed for reliable species-level identification (Fig. 2).

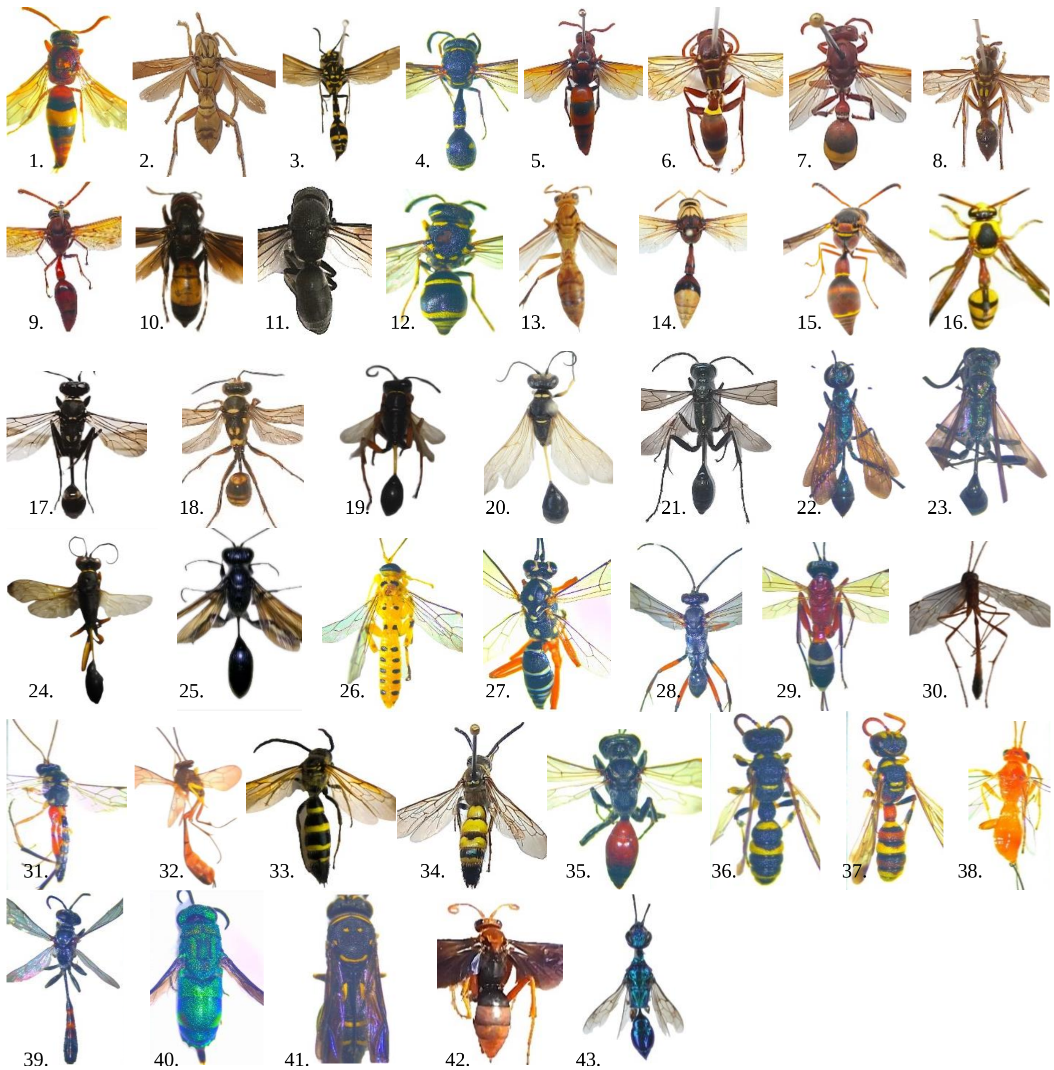

Fig. 2. Dorsal view of 1. 1. *Antodynerus flavescens,* 2. *Polistes olivaceus,* 3. *Phimenes flavopictum,* 4. *Eumenes inconspicuus,* 5. *Rhynchium brunneum,* 6. *Polistes stigma,* 7. *Ropalidia sp.,* 8. *Parapolybia varia,* 9. *Delta conoideum,* 10. *Vespa affinis,* 11. *Allorhynchium argentatum,* 12. *Antepipona ceylonica,* 13. *Polistes wattii,* 14. *Delta pyriforme,* 15. *Eumenes smithii,* 16. *Delta lepeleterii* 17. *Sceliphron sp.,*

18. *Sceliphron curvatum,* 19. *Sceliphron coromandelicum,* 20. *Sceliphron madraspatanum,* 21. *Chalybiom japonicum,* 22. *Chalybion sulawesii,* 23. *Chalybion bengalense,* 24. *Sceliphron lateum,* 25. *Isodontia Mexicana,* 26. *Xanthopimpla punctata,* 27. *Gotra marginata,* 28. *Stilpnus gagates,* 29. *Crytea tricolor,* 30. *Enicospilus combustus,* 31. *Leptobatopsis sp.,* 32. *Diadegma Bruxa,* 33. *Dielis trifasciata,* 34. *Campsomeris plumipe,* 35. *Mimesa equestris,* 36. *Cerceris sp.,* 37. *Cerceris albicincta,* 38. *Diachasmimorpha longicaudata,* 39. *Gasteruption sp.,* 40. *Chrysis sp.,* 41. *Leucospis dorsigera,* 42. *Tachypompilus ferrugineus,* 43. *Ampulex compressa.*

To support accurate identification and facilitate future studies on wasp diversity, dichotomous keys were developed based on the key morphological features observed in the collected specimens. These keys provide a practical tool for distinguishing species within each family and highlight important characters relevant to taxonomy.

Taxonomic keys

Family: Vespidae

1a. Fore wing containing third submarginal cell distinct from the apex of marginal cell by approximately half the width of marginal cell. Metanotum flat 3a

1b. Fore wing having the third submarginal cell detached at the apex of the marginal cell by a length of the submarginal cell. Metanotum angled 2a

2a. Scutellum impunctate 15b

2b. Scutellum punctate 3a

3a. Metasoma not petiolate...7b

3b. Metasoma petiolate and dark red...4b

4a. T2 with translucent apical lamella separated from disc by pre-apical thickening...9b

4b.T2 with apical lamella not preceded by thickening. T1 usually smooth 5a

5a. Clypeus smooth, pyriform, apex truncate and slightly emarginated 8b

5b. A wide U-shaped yellow mark on the clypeus middle, a short mark between the base of the clypeus and the plane of the upper margin of antennal sockets. ....*Phimenes flavopictum*

6a. Frons and clypeus shiny, thickly punctate 7a

6b. Frons sparsely punctured 13b

7a. Metanotum laterally with short teeth, flat in between 16b

7b. Metanotum lacking teeth ....*Allorhynchium argentatum*

8a. Petiole without an apical yellow band. Mesoscutum anteriorly yellow 9a

8b. Petiole with the apical yellow band. Mesoscutum variegated with red and black markings.. *Delta conoideum*

9a. Base to middle length Metasomal tergum 2 quickly becomes slender to the apical margin, with a deep longitudinal depression in the center of metasomal sternum 2 ....*Delta pyriforme*

9b. T1 in dorsal view is thread-like at the base, then quite visibly widened sharply toward the middle. T1 slender, in lateral view strongly swollen 15a

10a. In females, the occipital carina is incomplete. Mesoscutum, propodeum, and the final three metasomal terga are in different hues. Mainly yellow body with black lines on the femurs, pro pleuron, mesepisternum, metapleuron, coxae, and mesopleuron...11a

10b. The female occipital carina is complete. A black mark encloses the ocellus. Brownish mesonotum with no noticeable yellow stripes. Metasoma brown with yellow undertones 11b

11a. Back of epistomal (frontoclypeal) suture blackish or dark; Clypeus is consistently convex. ....*Polistes olivaceus*

11b. On back of epistomal suture yellowish; Clypeus with impression 12a

12a. Metasomal segment 1 subsessile, conical in dorsal view, laterally smoothly rounded. Propodeum with orifice acute ....*Polistes wattii*

12b. Metasomal segment 1 different shape, petiolate in dorsal view. Propodeum rounded ....*Ropalidia sp.*

13a. Propodeum having a less strong transverse striation. Large-scale yellow or reddish marks. 14a

13b. Propodeum having shallow, narrow fovea front, without conspicuous transverse striae ....*Antodynerus flavescens*

14a. Tergum IV devoid of the apical yellow band. Sterna II has posterolaterally spots, and Sterna III with an apical yellow band ....*Polistes stigma*

14b. First and second tergites are orange-yellow; and the base of the first is so extensively ferruginous as to be typical..17a

15a. Clypeus with short, broadly rounded lobes. 1st and 2nd abdominal segments are yellow 17b

15b. Clypeus very convex and pyriform, the apical third prominent with a large medial vertical groove, the extreme apex truncate or slightly incised. ....*Rhynchium brunneum*

16a. Metasomal terga, there are noticeable pale-yellow patterns that give it a brownish hue ....*Parapolybia varia*

16b. Yellow apical bands on the metasoma ....*Antepipona ceylonica*

17a. Head and antenna- mostly bright ferruginous.red....................*Vespa affinis*

17b. Antennae are segmented and black in shade ....*Eumenes inconspicuus*

18a. Propodeum extensive reddish...*Eumenes smithii*

18b. Propodeum with extensive yellow colour ....*Delta lepeleterii*

Family: Sphecidae

1a. Propodeum crosswise strigose-punctate 6b

1b. Propodeum dorsally transversely striate 4b

2a. Occasionally with a small (yellowish-brown) spot on the posterior surface of propodeum 3a

2b. Two yellow spots on anterolateral parts of propodeum in front of the spiraculum 5a

3a. Macula on the upper clypeal margin is yellowish brown...*Sceliphron coromandelicum*

4a. Petiole in lateral view distinctly straight...............*Sceliphron madraspatanum*

4b. Petiole sharply curved...*Chalybion japonicum*

5a. All legs red except coxae and trochanters, which are mostly black. ....*Sceliphron curvatum*

5b. The leg is entirely black ....*Isodontia mexicana*

6a. Metapleuron not striate..*Chalybion bengalense*

6b. Metapleuron striate ....*Sceliphron lateum*

7a. Ternum blue dark in colou..*Chalybion sulawesii*

7b. Ternum black with yellow in colour ....*Sceliphron sp.*

Family: Ichneumonidae

1a. Forewings with proximal and central sclerites ....*Enicospilus combustus*

1b. Forewings with hyaline sheath 2a

2a. Ovipositor 2x longer than hind tibia. 3b

2b. Ovipositor longer than the metasoma 3a

3a. Propodeum has longitudinal and transverse ridges 4b

3b. Propodeum has upper longitudinal carina 8b

4a. Antenna are 38-40 segmented 5a

4b. Antenna is 25-26 segmented 8a

5a. Metathoracic legs are entirely orange in color ....*Gotra marginata*

5b. Metathoracic coxae are entirely reddish brown 6b

6a. All three pairs if legs have tricolour; black, red and white ....*Crytea tricolor*

6b. All three pairs of legs have two colors: orange and black......*Leptobatopsis sp.*

7a. Spiracles located near to basal part of the 3rd metasomal segment 8a

7b. Spiracles with slight depression located on first metasomal tergite ....*Diadegma bruxa*

8a. Face densely covered with short setae ....*Stilpnus gagates*

8b. Face with close punctures .... *Xanthopimpla punctata*

Family: Crabonidae

1a. Propodeal enclosure slightly ridged and less shinny 2a

1b. Propodeal enclosure smooth and shiny..2b

2a. 1st gasteral tergite is black ....*Cerceris sp.*

2b. 1st gasteral tergite is red ....*Cerceris albicincta*

3a. Scrobal sulcus not strongly impressed, hypoepimeral region is poorly.defined, tends to be strongly punctate or ridged compared to the median area in mesopleuron ....*Mimesa equistris*

Family: Scoliidae

1a. Hind tibial spurs are black 2a

1b. Hind tibial spurs are white 2b

2a. Pronotum is entirely black ....*Dielis trifasciata*

2b. Pronotum is entirely black...*Campsomeris plimipes*

Family: Braconidae

1a. Metasoma and fore femur black; hind femur length about 4 times in breadth, humeral plate pale, yellowish; mesosoma bright, orange-brown. ....*Diachasmimorpha longicauda*

Family: Gasteruptiidae

1a. Each antenna has thirteen or fourteen sections ....*Gasteruption sp.*

Family: Chrysididae

1a. A latitudinal row of more than 4 small pits; Wings Sclerotized, or vein enclosing cell dark and distinct; Abdomen convex, curved, and or filled outward; posterior margin of T3 with 5 notches and 6 teeth or rarely without teeth .... *Chrysis sp.*

Family: Leucospidae

1a. Metafemur enlarged with teeth, and strongly curved metatibia; without infuscate apical spot ....*Leucospis dorsigera*

Family: Pompliidae

1a. Reddish orange body with conspicuous iridescent blue to violet wings ....*Tachypompilus ferrugineus*

Family: Ampulicidae 1a. All spiracles are brown and located inside pronounced depressions; 6 punctures on subgenal area; Body covered with 1 – 2 µm spines ....*Ampulex compressa*

After the completion of species identification, their abundance, depending on seasons and habitat, had become easier to discuss, and the frequency comparison among the families presents the most dominant group of wasps within the suburban regions in Dhaka.

Dominance and relative abundance of wasp families: The chart (Fig. 3) segments representing the relative percentages of different families provided a clear visualization of the dominance of specific wasp families. The Vespidae family had the highest abundance at 40%, followed by Sphecidae (27%) and Ichneumonidae (9%). Leucospidae had the lowest relative abundances (0.3%). A total of 937 individuals belonging to 16 different species of the family Vespidae were observed, whereas only 7 individuals of 1 species were found under the family Leucospidae.

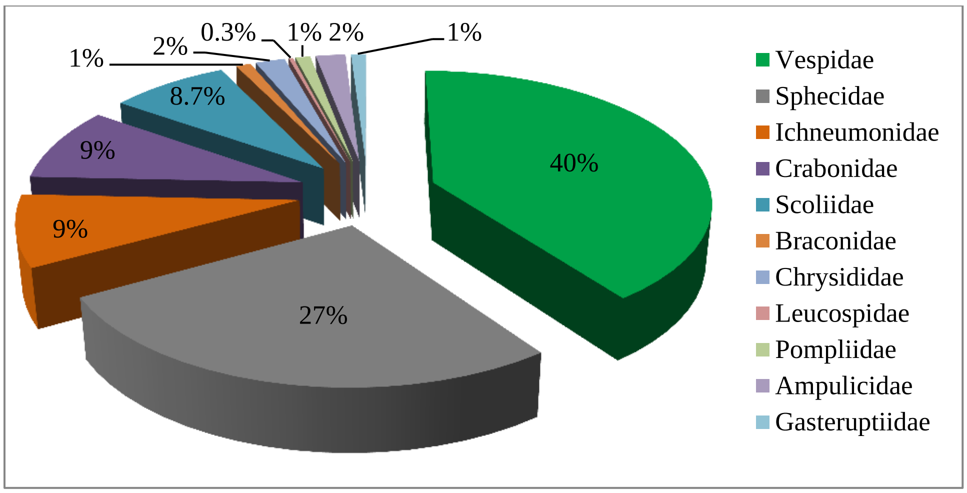

Fig. 3. Family dominance among the observed wasp population

Biodiversity indices and community structure: Table 2 presents the biodiversity indices for five wasp families that were most frequently observed within the community, highlighting species diversity, richness, and dominance. The higher diversity of Vespidae was assumed with the indices of Shannon-Wiener Index (2.221), Simpson's Index (0.146), and Simpson's Reciprocal Index (6.834). The Dominance Index (0.271) indicated strong dominance by Scoliidae in the community with a lower range of diversity. Crabonidae has the most even distribution (J' = 0.977), while Scoliidae is the least even (J' = 0.636). Margalef Diversity Index reflects species richness, where Vespidae (D_{Mg} = 2.192) is the richest in species.

Table 2. Diversity indices of the frequent wasp families

Family	Shannon-Wiener Index (H')	Margalef Diversity Index (D_{Mg})	Pielou's Evenness Index (J')	Simpson's Index (D)	Simpson's Reciprocal Index (1/D)	Dominance Index (1 - D)
Vespidae	2.221	2.192	0.801	0.146	6.834	0.853
Sphecidae	1.777	1.238	0.808	0.196	5.087	0.803
Ichneumonidae	1.698	1.129	0.872	0.206	4.853	0.793
Crabonidae	1.074	0.375	0.977	0.345	2.895	0.654
Scoliidae	0.441	0.188	0.636	0.728	1.372	0.271

Bipartite network analysis of species-habitat associations: Fig. 4 illustrates ecological relationships between insect families and habitats using a matrix-style heat map. Rows represent insect habitats, columns represent insect families, and blue squares indicate associations. Vespidae had the most connections (9 out of 14), followed by Sphecidae, while Pompillidae, Leucospidae, Gasteruptiidae, Chrysidae, Braconidae, and Ampulidae had few. Certain habitats, like plant families Fabaceae and Asteraceae, supported multiple wasp families. This visualization supports ecological studies by analyzing species-habitat interactions, crucial for conservation and biodiversity research.

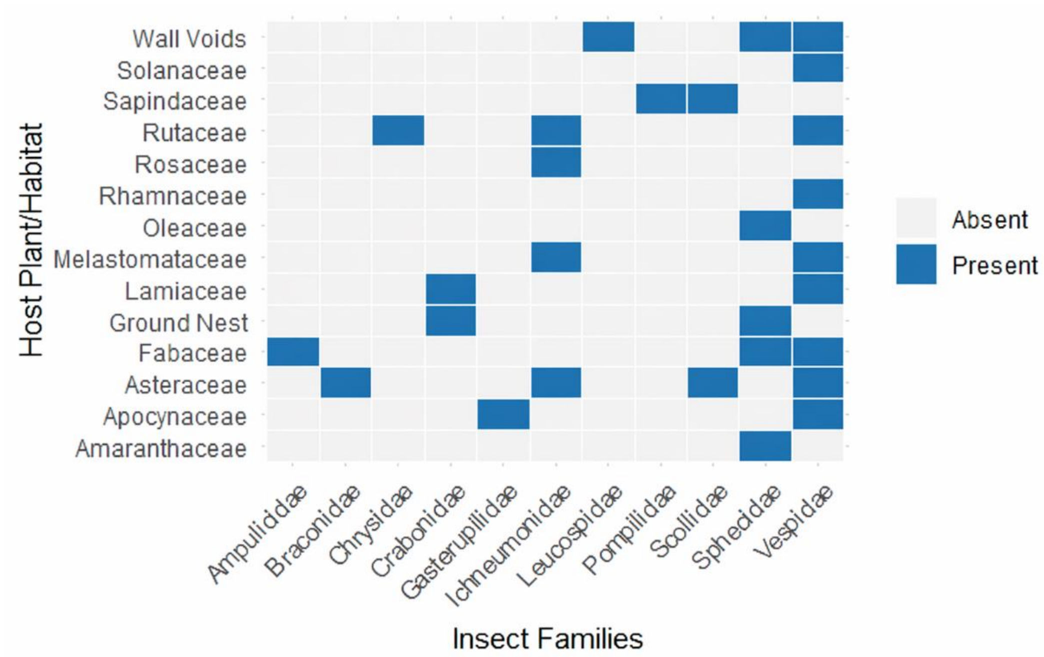

Fig. 4. Bipartite network correlating the insect families with their associated habitats

Seasonal activity patterns via heatmap analysis: The heatmap (Fig. 5) shows the presence of insects over the year, with darker shades of green representing a larger count and the lighter shades representing smaller counts. Some species, like *P. watti* (252 counts) and *P. olivacus* (189), peaked early in the year (March), while *Dielis sp.* (167) was more active in May. Others, like *X. punctata* and *T. ferrugineus*, and many others showed sporadic occurrences. Overall, insect activity was lower from October to January, likely due to environmental factors that effectively revealed seasonal variations in insect presence. This study presents a comprehensive assessment of wasp biodiversity in suburban Dhaka, documenting 43 species across 11 families - substantially more than the 14

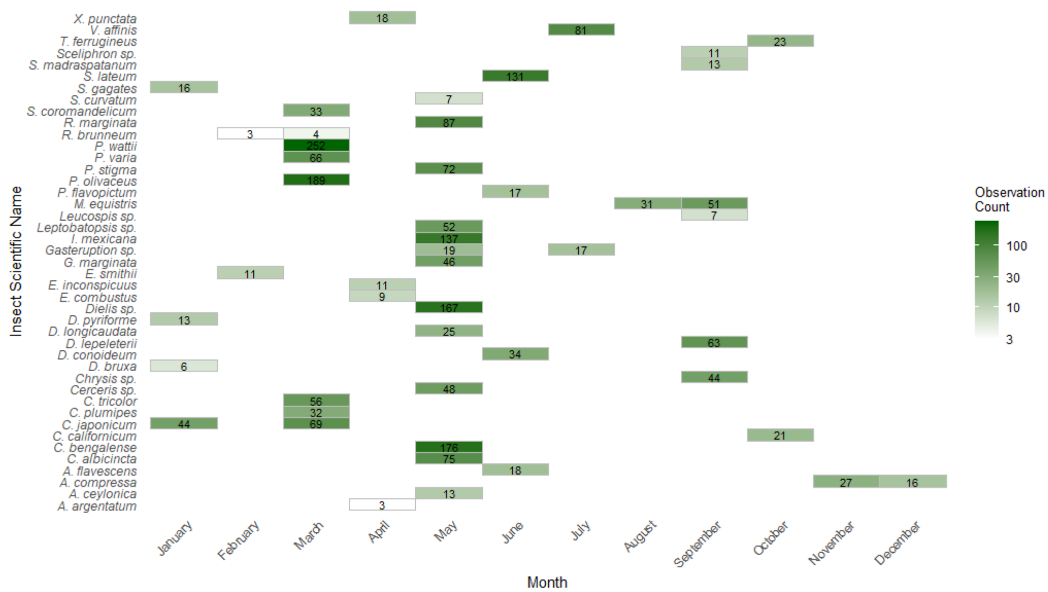

Fig. 5. Heatmap suggesting different seasonal activity patterns exhibited by studied taxa

species from four families previously reported by Akter *et al.* (2020) in the city area. The presence of diverse wasp families, including predators (Vespidae, Sphecidae), parasitoids (Ichneumonidae, Braconidae), and pollinators (Chrysidae, Scoliidae), underscores their ecological significance in maintaining ecosystem balance (Hanson and Gauld, 2006). Vespidae emerged as the most diverse family, consistent with prior studies, where Vespidae dominate urban and suburban landscapes due to their adaptive foraging behavior and broad nesting preferences (Carpenter and Kojima, 1997; Pickett and Carpenter, 2010). Sphecidae and Ichneumonidae showed moderate diversity, aligning with observations that urban habitat fragmentation affects species abundance (Gathmann and Tscharntke, 2002). Families such as Gasteruptiidae, Scoliidae, and Leucospidae were less represented, possibly due to ecological specialization or sensitivity to urbanization (Wilson and Holway, 2010; Deguines *et al.,* 2016). These findings underscore the impact of anthropogenic activities on wasp diversity in suburban landscapes. Heatmap analysis showed peak wasp activity in warmer months, reflecting seasonal foraging patterns influenced by temperature and resource availability (Richards, 2001; Polidori *et al.,* 2020). The marked decline in activity during cooler months is likely driven by a reduction in these essential resources and a cessation of nesting activities for many species (Nascimento *et al.,* 2020).

CONCLUSION

This study documents 43 wasp species across 11 families from suburban regions of Dhaka, with Vespidae emerging as the most dominant and species-rich group. Biodiversity indices revealed clear variations in diversity, dominance, and evenness among families, while habitat association and seasonal activity patterns underscored the ecological importance of wasps in suburban ecosystems. The dichotomous keys developed in this study will facilitate reliable species identification and provide a valuable resource for future taxonomic and ecological studies. By filling a critical knowledge gap in Bangladesh, this work establishes essential baseline data for biodiversity monitoring and conservation in rapidly urbanizing landscapes. To safeguard these ecologically important insects, strategies such as habitat preservation, reduced pesticide use, and urban greening are recommended, while future research should integrate long-term monitoring and molecular approaches to refine taxonomy and better understand functional ecological roles.

LITERATURE CITED

AKTER, T., JHARNA, J. A., SULTANA, S., AKHTER, S., and BEGUM, S. 2020. Identification and ecology of wasps (Apocrita: Hymenoptera) of Dhaka city. *Bangladesh Journal of Zoology.* **48**(1): 37-44.

BOHART, R. M., and MENKE, A. S. 1976. *The Family Sphecidae: Sphecid Wasps of the World. A Generic Revision.* University of California Press, Berkeley. 696 pp.

BROCK, R. E., CINI, A., and SUMNER, S. 2021. Ecosystem services provided by aculeate wasps. *Biological Reviews.* **96**(4):1645-1675.

BUCK, M., MARSHALL, S. A., and CHEUNG, D. K. 2008. Identification Atlas of the Vespidae (Hymenoptera, Aculeata) of the northeastern Nearctic region. *Canadian Journal of Arthropod Identification.* **5**(1): 1-492.

CARPENTER, J. M., and KOJIMA, J. 1997. Checklist of the species in the subfamily Polistinae (Hymenoptera: Vespidae). *American Museum Novitates.* **3199**:1-39.

DEGUINES, N., JULLIARD, R., DE FLORES, M., and FONTAINE, C. 2016. Functional homogenization of flower visitor communities with urbanization. *Ecology and Evolution.* **6**(7):1967-1976.

DOWTON, M., and AUSTIN, A. D. 1994. Molecular phylogeny of the insect order Hymenoptera: apocritan relationships. *Proceedings of the National Academy of Sciences.* **91**(21): 9911-9915.

FAETH, S.H., BANG, C., and SAARI, S. 2011. Urban biodiversity: patterns and mechanisms. *Annals of the New York Academy of Sciences.* **1223**(1): 69-81.

FOOTTIT, R. G., and ADLER, P. H. 2017. *Insect Biodiversity: Science and Society*. John Wiley and Sons. 265 – 301 pp.

GATHMANN, A. and TSCHARNTKE, T. 2002. Foraging ranges of solitary bees. *Journal of Animal Ecology.* **71**(5):757-764.

GULMEZ, Y., and CAN, I. (2015). First record of *Sceliphron (Hensenia) curvatum* (Hymenoptera: Sphecidae) from Turkey with notes on its morphology and biology. *North-Western Journal of Zoology.* **11**(1): 174-177.

HALL, D. M., CAMILO, G. R., TONIETTO, R. K., OLLERTON, J., AHRNE, K., ARDUSER, M., and THRELFALL, C. G. 2017. The city as a refuge for insect pollinators. *Conservation Biology.* **31**(1):24-29.

HANSON, P.E. and GAULD, I.D., eds. 2006. *Hymenoptera De La Region Neotropical.* Gainesville: *American Entomological Institute.***77**: 694-733.

LASALLE, J. and GAULD, I. D. 1993. Hymenoptera: Their diversity, and their impact on the diversity of other organisms. *Biodiversity and Conservation.* **2**(2):120-130.

MARGALEF, R. 1958. Information Theory in Ecology. *General Systems.* **3**: 36-71.

MAZUMDAR, S. and MIAH, M. I. 2019. Diversity and abundance of parasitic wasps (Insecta: Hymenoptera) of Bangladesh. *Journal of Biodiversity Conservation and Bioresource Management.* **5**(2): 63-68.

MAZUMDAR, S., HEBERT, P. D., MIAH, M. I., and REDDY, G. V. 2023. Non-Chalcidoid Wasps Recorded in Bangladesh: Sustainable Approaches to The Biological Control of Arthropod Pests. *Munis Entomology and Zoology Journal.* **18**(2):1090-1124.

MCKINNEY, M. L. 2002. Urbanization, biodiversity, and conservation. *BioScience.* **52**: 883- 890.

MIM, N. T., SARKER, S., and ASLAM, A. F. M. 2024. COI gene–based molecular identification of honey bees (*Apis* spp.) from Bangladesh. *Bangladesh Journal of Zoology.* **53**(2): 137–148.

MORENO, M. and GIRALT, E. 2015. Three valuable peptides from bee and wasp venoms for therapeutic and biotechnological use: melittin, apamin and mastoparan. *Toxins.* **7**(4): 1126-1150.

NASCIMENTO, F. S., TANNURE-NASCIMENTO, I. C., ZUCCHI, R., and TAVARES, M. G. 2020. Seasonal patterns and foraging strategies of social wasps. *Insectes Sociaux.* **67**(4):637-647.

PICKETT, K. M. and CARPENTER, J. M. 2010. Simultaneous analysis and the origin of eusociality in the Vespidae (Insecta: Hymenoptera). *Arthropod Systematics & Phylogeny.* **68**(1):3-33.

PIELOU, E. C. 1966. The Measurement of Diversity in Different Types of Biological Collections. *Journal of Theoretical Biology.* **13**: 131-144.

PILOSOF, S., PORTER, M. A., PASCUAL, M., and KEFI, S. 2017. The multilayer nature of ecological networks. *Nature Ecology and Evolution.* **1**(4): 0101.

POLIDORI, C., JORGE, A., ORNOSA, C., and LÓPEZ-RIQUELME, G. O. 2020. Seasonal trends and environmental factors affecting wasp species richness in Mediterranean habitats. *Scientific Reports.* **10**(1):1-12.

R CORE TEAM. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. 68 pp.

RAHMAN, M. T., & ASLAM, A. F. M. 2025. Ecological assessment and DNA barcoding of major pollinators of *Ziziphus mauritiana* in Bangladesh. *Nepalese Journal of Zoology*. **9**(1): 9-17.

RAUPP, M.J., SHREWSBURY, P.M., and HERMS, D.A. 2010. Ecology of herbivorous arthropods in urban landscapes. *Annual Review of Entomology*. **55**(1): 19-38.

RICHARDS, O. W. 2001. *The Social Wasps of the Americas*. British Museum of Natural History.

SHANNON, C. E., and WEAVER, W. 1949. *The Mathematical Theory of Communication*. University of Illinois Press. 17 pp.

SHARKEY, M. J. 2007. Phylogeny and classification of Hymenoptera. *Zootaxa*. **1668**(1):521-548.

SIMPSON, E. H. 1949. *Measurement of Diversity*. Nature. **163**: 688.

SUMNER, S. 2021. Opinion: why I love wasps, and why you should too. Retrieved from UCL: https://www.ucl.ac.uk/news/2021/apr/opinion-why-i-love-wasps-and-why-you-should-

WAHED, A., YOSRI, N., SAKR, H. H., DU, M., ALGETHAMI, A. F., ZHAO, C., and EL- SEEDI, H. R. 2021. Wasp venom biochemical components and their potential in biological applications and nanotechnological interventions. *Toxins*. **13**(3): 206.

WILKINSON, L. and FRIENDLY, M. 2009. The History of the Cluster Heat Map. *American Statistician*. **63**(2): 179–184.

WILSON, E. O. 2021. *Biodiversity*. Harvard University Press. 75 pp.

WILSON, J. S. and HOLWAY, D. A. 2010. Urban areas as refuge for declining pollinators. *Journal of Insect Conservation*. **14**(6):617-626.

ZHANG, T., JANDER, K. C., HUANG, J. F., WANG, B., ZHAO, J. B., MIAO, B. G., and HERRE, E. A. 2021. The evolution of parasitism from mutualism in wasps pollinating the fig, *Ficus microcarpa*, in Yunnan Province, China. *Proceedings of the National Academy of Sciences*. **118**(32): e2021148118.

(Manuscript received on 20 September 2025 revised on 20 April 2026)