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RESEARCH ON THE DIVERSITY AND DISTRIBUTION OF APIDAE BEES (HYMENOPTERA: APOIDEA) IN THE SOUTHEAST REGION OF VIETNAM

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INTRODUCTION

1.1 The urgency of the dissertation

The Southeast region is an important ecological area, acting as a transitional zone between the South Central Coast and the Central Highlands, and the Mekong Delta. This region has a large area, diverse terrain with elevation decreasing from the Northwest to the Southeast, and a hot, humid tropical monsoon climate, creating favorable conditions for the development of diverse habitats and vegetation. Natural forests, fruit orchards, industrial crops, and agricultural lands have formed a rich plant resource, contributing to the maintenance of a diverse insect fauna, particularly bees.

Bees of the family Apidae are a diverse group with about 6,000 species recorded worldwide, including honeybees, bumblebees, stingless bees, and many solitary bees. This group plays an important role in ecosystems through pollination of natural plants and crops, contributing to biodiversity maintenance and agricultural productivity. In addition, bees provide economic value through products such as honey, beeswax, and propolis. However, in recent years, bee populations have been declining globally due to habitat loss, agricultural chemicals, environmental pollution, and climate change.

In Vietnam, studies on Apidae bees are still limited, mainly focusing on a few economically valuable species and mostly conducted in the North region. In the Southeast region, research on species composition, habitat distribution, altitudinal gradients, floral resources, and nest biology of bees is still lacking and unsystematic. Meanwhile, this area is experiencing rapid urbanization, increased chemical use, and reduced natural forest area, factors that strongly affect food sources, nesting sites, and bee distribution.

Therefore, studying the diversity of species composition, distribution characteristics, and nest biology of Apidae bees in the Southeast region is essential. The results will not only contribute to scientific data on bee fauna in Vietnam but also provide a basis for biodiversity conservation, pollinator resource management, and sustainable agricultural development. Hence, I conducted the study: ***"Research on the diversity and distribution of Apidae bees (Hymenoptera: Apoidea) in the Southeast region of Vietnam."***.

1.2 Research objectives

To determine the diversity of species composition and distribution characteristics of Apidae bees in the Southeast region of Vietnam.

1.3 Research contents

- Study the diversity of Apidae bees in the Southeast region.
- Classify, identify, and construct a taxonomic key for Apidae bees.
- Determine the distribution characteristics of Apidae bees in the study area.
- Record nest biology characteristics of some Apidae bees in the Southeast region.

1.4 Scientific and practical significance

Scientific significance:

The study clarifies the diversity of Apidae bees, thereby supplementing biodiversity data on bees in Vietnam. The species list, newly recorded species, additional species, taxonomic keys, distribution characteristics, and nest biology are important data for biodiversity research and conservation in the Southeast region.

Practical significance:

The study’s data support the development of beekeeping and conservation of bee species towards sustainability, thereby contributing to ecosystem protection and maintaining bee-derived benefits for local communities. Furthermore, information on nest biology of certain agriculturally valuable species will play an important role in protecting these pollinators.

1.5 New contributions of the study

- The study has established a comprehensive and systematic list of Apidae bees, provided taxonomic keys to genus and species level for Apidae bees in the Southeast region of Vietnam.
- For the first time, nest biology data of four *Xylocopa* species have been added, clarifying nesting sites and nest structures, contributing to a deeper understanding of Apidae bee ecology in the Southeast region of Vietnam.

Chapter 1: LITERATURE REVIEW

Overview of the study area

The Southeast region is one of the two areas of Southern Vietnam. It covers nearly 30,000 km², accounting for more than 8% of the country's total area. The region includes three provinces/cities: Tay Ninh, Dong Nai, and Ho Chi Minh City, which are major economic centers of Vietnam. Geographically, it connects the South Central Coast and Central Highlands with the Mekong Delta.

Natural forests and fruit orchards are distributed across all three areas. The diversity of forest and agricultural ecosystems contributes to high biodiversity, including bee species. However, published studies show that research on Apidae bees in this region remains limited. Therefore, studying species diversity and distribution of Apidae bees here is essential.

Research status

The global research status of the bees in the Apidae family

a. Species diversity and taxonomy

Worldwide, the family Apidae exhibits high levels of diversity, with more than 6,000 species across over 200 genera, distributed across all continents. The Americas represent the richest region, exemplified by Brazil, which hosts more than 1,000 species. Among the genera, *Nomada* is the most diverse (approximately 800 species), followed by *Anthophora*, *Xylocopa*, *Ceratina*, and *Centris*. In contrast, the genus *Apis*, which is most familiar to humans, is the least diverse, comprising only 7–11 species, primarily distributed in Asia.

Stingless bees also display remarkable diversity, with around 600 species concentrated in tropical regions of the Americas, Southeast Asia, and Australia. Additionally, the subfamily *Xylocopinae* includes more than 1,000 species, with *Xylocopa* and *Ceratina* widely distributed worldwide, each represented by approximately 400 species. Overall, global studies have demonstrated the substantial species diversity of Apidae bees, while continuously adding newly described species, developing identification keys, and expanding knowledge of their biology, ecology, and conservation, underscoring the importance of this pollinator group.

b. Distribution of apidae bees

The distribution of Apidae bees is strongly influenced by habitat, elevation, and environmental conditions. Natural forests maintain the highest species diversity, whereas secondary habitats and residential areas are often dominated by species with broad ecological tolerance, such as *Apis*. Species richness generally peaks at mid-elevations and declines at both very low and very high altitudes. In agricultural ecosystems, particularly fruit orchards, bee diversity depends largely on landscape structure, floral resources, and proximity to natural habitats.

c. Studies on floral resources

Global studies have documented extensive diversity in floral resources visited by Apidae bees, reflecting their central role in pollination networks. From early work by Schwarz (1939) on *Trigona* visiting *Mimosa pudica* and various crops, to Sakagami's studies (1967, 1973) reporting hundreds of bee species visiting flowers in Brazil and Japan, evidence consistently highlights Asteraceae and Fabaceae as the most important plant families. More recent research in Singapore, Chile, Denmark, and Australia has further confirmed the richness of Apidae bees and their close associations with numerous native plants and cultivated species.

d. Studies on nest biology

Research worldwide has revealed considerable diversity in nesting behavior, floral resources, and ecological roles among Apidae bees. *Apis mellifera*, *A. cerana*, *A. dorsata*, and *A. florea* have been extensively studied, showing marked differences in nest location and structure. Stingless bees, comprising more than 600 species primarily in tropical regions, typically nest in hollow trees, underground, or artificial structures, with complex nest architecture and highly social behavior. Large carpenter bees (*Xylocopa*) are of particular interest due to their effective pollination of both crops and wild plants, with adaptations for nesting in dead wood, bamboo, or hollow stems. However, climate change, habitat loss, and competition with introduced species pose serious threats to native bee populations. Recent studies in Southeast Asia, particularly in Vietnam, the Philippines, Thailand, and

Singapore, have documented significant declines in genetic diversity and population sizes of Apidae bees, underscoring the urgent need for conservation and further research.

Research on Apidae bees in Vietnam

a. Species diversity and taxonomy

In Vietnam, more than 60 Apidae bee species have been recorded, distributed across 10 tribes and approximately 15 genera within three subfamilies: *Apinae*, *Nomadinae* and *Xylocopinae*. Common genera include *Amegilla*, *Apis*, *Bombus*, *Ceratina*, *Thyreus*, *Tetragonula*, *Homotrigona*, and *Lepidotrigona*. Research on Apidae bees in Vietnam began in the 19th century, with Rialan (1887) documenting *Apis mellifica* in Thai Nguyen Province. Subsequent studies largely focused on domesticated honey bees for honey production and export. Notable works include Phung and Pham (2004), who studied the biology, ecology, and beekeeping techniques of common *Apis* species. Nguyen (2004, 2007), who investigated the behavior of *A. dorsata* in Ca Mau melaleuca forests. Le (2013), who distinguished *A. dorsata* from *A. laboriosa*, and Nguyen (2017), who identified 60 Apidae species in northern Vietnam, including several newly recorded species. Beyond *Apis*, stingless bees have also attracted research interest. Overall, Apidae studies in Vietnam have a long history but remain concentrated on domesticated species, while wild and stingless bees have only recently begun to receive attention.

b. Distribution of apidae bees

Studies indicate that Apidae bees in Vietnam are primarily distributed in natural forest habitats, which support the highest species diversity. Some species, such as *Apis cerana*, exhibit broad ecological adaptability and occur across multiple habitat types. Elevational distribution has been preliminarily documented, with species richness highest at mid-elevations. In agricultural ecosystems, particularly fruit orchards, bees play a crucial role in pollination. However, research on distribution remains fragmented and uneven across regions.

c. Floral resources

Floral resources for bees in Vietnam have mainly been studied in domesticated *Apis* species, with fruit trees and industrial crops such as litchi, longan, coffee, and cashew serving as primary food sources. Some wild bee species have also been recorded visiting other plant groups, though information remains limited. Current studies are largely descriptive and have yet to clarify the detailed interactions between bees and plants.

d. Nest biology of Xylocopa

Nest biology of honey bees and stingless bees in Vietnam has been relatively well studied, revealing diverse nest structures and nesting behaviors. However, research on carpenter bees (*Xylocopa*) remains scarce and has been concentrated mainly in northern Vietnam. Information on nest structure, materials, and nesting behavior is still lacking, particularly in other regions such as Southeastern Vietnam.

Research on apidae bees in Southeastern Vietnam

a. Species diversity and taxonomy

Studies conducted between 1975 and 2025 on honey bees and stingless bees of the family Apidae in Vietnam reveal that data for the Southeastern region remain limited and fragmented. Initially, only a few individuals were recorded (*Trigona fimbriata* at Ba Den Mountain, *Lepidotrigona terminata* in Ho Chi Minh city). Later, a checklist of 18 species was compiled for Tay Ninh, Dong Nai, and Binh Phuoc, though lacking habitat and elevational information. In 2021, a survey in Binh Chanh (Ho Chi Minh City) provided more detailed data, documenting 169 individuals of 13 species, and highlighting high species diversity in forest habitats and during the dry season. In 2025, Vu et al. confirmed the distribution of *Tetragonula pagdeni* in Southeastern Vietnam and the Mekong Delta, while correcting earlier misidentifications with *T. iridipennis*. The most recent checklist reports 55 Apidae species in Vietnam, of which 8 occur in Southeastern Vietnam. However, information on distribution and habitat remains incomplete, underscoring the need for further research in this region.

b. Distribution of apidae bees

Distributional data remain scattered, primarily documenting species presence without detailed analysis by habitat or elevation. Preliminary studies suggest higher species diversity in natural forest habitats, but comprehensive research on distribution across other ecosystems, such as fruit orchards or along elevational gradients, is still lacking.

c. Floral resources

Research on floral resources of Apidae bees in Southeastern Vietnam since 2008 has been limited and largely descriptive. *Xylocopa* species are often associated with Cucurbitaceae, while *Apis*, *Thyreus*, and *Tetragonula* are linked to Fabaceae and Asteraceae. *Ceratina* species have been observed visiting flowers of *Solanum*, *Chromolaena odorata*, and *Ipomoea*, whereas *Amegilla* species are associated with *Ipomoea*. Overall, data on floral resources remain scarce, with only preliminary records of floral spectra for different bee groups, and bee–plant interactions are still absent.

d. Nest biology of Xylocopa

Virtually no studies have been conducted on the nest biology of Apidae bees in Southeastern Vietnam. In particular, carpenter bees (*Xylocopa*), despite their important ecological role, lack data on nesting behavior and nest structure.

Although some preliminary studies have been conducted at varying scales and scopes, overall data on Apidae bees in Southeastern Vietnam remain insufficient, fragmented, and fail to fully reflect the region's biodiversity potential. Comprehensive research on species diversity, distribution, floral resources, and nest biology of Apidae bees in Southeastern Vietnam is therefore essential. It is not only to supplement and refine the regional bee fauna database but also to clarify ecological characteristics, bee–plant interactions, and species adaptability to environmental changes.

Chapter 2 : MATERIALS AND METHODOLOGY

2.1. MATERIALS

2.1.1. Materials

The study focused on bee species belonging to the *Apidae family*, *Hymenoptera order*, *Insecta class* in Southeastern Vietnam.

2.1.2. Research scope

The study on species diversity and distribution of bees was conducted from 2022 to 2025, focusing on 18 districts and towns across six former provinces and cities, corresponding to 26 communes and wards within three current provinces/cities: Tay Ninh, Dong Nai, and Ho Chi Minh City. Survey sites were established across various habitat types, including natural forests, shrublands, and residential areas, and were distributed along elevational gradients ranging from below 50 m, 50–200 m, 200–500 m, to above 500 m. A total of 26 sites were surveyed, where data were recorded and specimens were collected. Among these, 11 sites included records of bee nests, and 2 sites involved the use of Malaise traps in fruit orchards for specimen collection. Of the sites where bee nests were found, six locations were surveyed and sampled for nests of the genus *Xylocopa*, including An Ninh, Chanh Hiep, Binh Duong, Thuan An, An Thoi Dong, and Tan Trieu.

Field surveys and bee sampling were primarily conducted during the dry season, from December to April each year. Bee specimens from three fruit orchards in Binh Minh Ward and Duong Minh Chau Commune (Tay Ninh Province) were also collected during the dry season, from February to May 2023. Additionally, several supplementary surveys were carried out in June 2023, August–September 2024, and October 2025, mainly in Ho Chi Minh City.

2.2. Research Methods

2.2.1. Field Methods

In the field, bee specimens were collected using insect nets, nest sampling, and Malaise traps.

Sampling using insect nets

Apidae bee specimens were collected along survey transects using insect nets. Transects were typically established along trails, paths, or open areas with abundant flowering plants to maximize sampling efficiency. Bee sampling followed the methods of Sakagami et al. (1973), Soh et al. (2013), Popic et al. (2013), and Nguyen (2017), with modifications adapted to local sampling conditions and the study area.

Qualitative survey transects for recording species composition ranged from approximately 500 m to 2000 m in length. Along these transects, bees observed in flight, visiting flowers, or near nesting sites were recorded and collected. Qualitative samples were collected by the principal investigator and supporting team members. Each specimen was preserved in separate vials labeled with collection locality information.

To ensure comparability in the number of individuals collected across habitats, elevational gradients, and plant species, quantitative sampling was conducted along standardized transects. Each quantitative transect was approximately 100 m in length, with continuous sampling carried out for 2 hours. To minimize bias related to collector technique and sampling time, all quantitative samples were collected by the principal investigator during dry-season surveys. A total of 72 quantitative samples were conducted across three habitat types and four elevational ranges within the study area.

During sampling periods, bees observed on flowers or in flight were randomly collected. Specimens from different locations and floral hosts were stored in separate labeled vials. After each survey site, samples were transferred into plastic containers along with detailed information on floral resources and collection locality.

Bee nest surveys

During field surveys, and with assistance from local authorities and residents, nests of several bee taxa, including *Apis*, *Xylocopa*, and stingless bees, were located. These bees typically nested on branches, tree trunks, or at the base of trees in natural forest habitats or residential areas. Nests of some *Apis* species and stingless bees were commonly found on large branches or trunks of large old trees in natural forests. For these nests, only observational data were recorded, including location, nesting plant species, and nest entrance characteristics, without collecting nest samples. In contrast, nests of *Xylocopa* species, typically found in dead wood (branches or trunks) in areas surrounding residential habitats, were observed, documented, and collected. These samples were transported to the laboratory for analysis of nest biology and structural characteristics.

Recording floral resources

At survey sites and quantitative sampling locations, flowering plants visited by bees were photographed and recorded. Plant species that could not be identified in the field were collected for later identification in the laboratory. Additionally, floral resources surrounding *Xylocopa* nests were surveyed and documented.

Sampling using Malaise traps

At each fruit orchard, one trap was installed in the central area. A total of 84 trap-days were conducted, with 12 sampling events during the dry season of 2023. Traps were deployed during the dry season when weather conditions were favorable for bee activity, particularly for ground-nesting species. This period also coincides with the flowering season of many fruit trees and wild plant species in the orchards. The trapping solution used was 90% ethanol. Samples were collected weekly, and the ethanol was replaced after each collection. All collected specimens were subsequently transported to the laboratory for further analysis.

2.2.2. Laboratory Methods

In the laboratory, bee specimens collected using insect nets were sorted to genus level, pinned, and oven-dried. Specimens obtained from Malaise traps were rinsed, preserved in 70% ethanol, and identified under a microscope. *Xylocopa* nests were dissected, and their structural characteristics were measured using digital calipers, while adult individuals were processed using ethyl acetate. Identification keys were constructed to the genus and species levels. These keys were developed based on morphological characteristics of female specimens. Terminology and diagnostic characters used for identification and key construction followed

Michener (2007), Karunaratne and Edirisinghe (2008), and Tran (2023). In addition, the study examined bee distribution across different habitat types (natural forests, shrublands, and residential areas), elevational gradients (from below 50 m to above 500 m), fruit orchards, and floral resource plants.

2.2.3. Statistical Analysis

Data on species composition and abundance of honey bees were processed using Microsoft Excel 2016. Diversity and similarity indices of bees across habitats, elevational gradients, and fruit orchards were calculated and analyzed using PRIMER VI and R.

The Shapiro–Wilk test and Levene's test were applied to assess normality and homogeneity of variances for species richness, abundance, and diversity indices. For variables meeting these assumptions, one-way analysis of variance was performed. In contrast, for variables that did not meet the assumptions, the non-parametric Kruskal–Wallis test was used.

The relationships between bee species richness and abundance with floral resource plant richness were evaluated using linear regression in R. In addition, bar charts and bubble plots were used to illustrate variations in bee abundance and species richness across habitats and elevational gradients.

To analyze interactions between bees and floral resources, an interaction network was constructed using the *bipartite* package in R. Basic nest parameters, including overall nest size, cell size, and structural components, were measured using digital calipers to ensure high accuracy. These data were subsequently processed and analyzed in Excel and R, providing a detailed description of nest morphology and structure.

Chapter 3: RESULTS AND DISCUSSION

3.1 Species diversity of apidae bees

3.1.1 Species composition

Research conducted in Southeastern Vietnam from 2022 to 2025 identified 45 species belonging to 11 genera and 2 subfamilies of Apidae bees. These include the subfamily *Apinae* with 23 species across 8 genera, and *Xylocopinae* with 22 species across 3 genera. Among these, three genera and 23 species were newly recorded for the Southeastern region, and *Xylocopa acutipennis* was documented as a new record for the bee fauna of Vietnam (Table 3.1).

Within Southeastern Vietnam, Dong Nai Province exhibited the highest species diversity, with 38 species across 11 genera. Ho Chi Minh City recorded 28 species, while Tay Ninh Province documented 26 species, both representing 8 genera. Of the 11 genera, *Bombus*, *Homotrigona*, and *Lisotrigona* were newly discovered in Dong Nai Province. The remaining genera were distributed across all three surveyed areas in Southeastern Vietnam (Table 3.1).

Table 3.1. Species composition of Apidae bees in Southeastern Vietnam

PHYLUM ARTHROPODA					
CLASS INSECTA					
ORDER HYMENOPTERA					
FAMILY APIDAE					
No.	**Taxa**	**Province /City**	**Number of Individuals**	**Abundance n' (%)**	**Frequency C (%)**
I	**Subfamily Apinae**				
I.1	***Genus Amegilla***				
1	*Amegilla calceifera* (Cockerell, 1911)	HCM, ĐN, TN	13	0,7	15,3
2**	*Amegilla cingulata* (Fabricius, 1775)	ĐN	1	0,1	1,4
3**	*Amegilla confusa* (Smith, 1854)	HCM, ĐN, TN	5	0,3	5,6
4	*Amegilla fimbriata* (Smith, 1879)	HCM	2	0,1	1,4
5	*Amegilla himalajensis* (Radoszkowski, 1882)	HCM	3	0,2	2,8
6	*Amegilla zonata* (Linnaeus, 1758)	HCM, ĐN, TN	55	3,1	37,5
I.2	***Genus Apis***				
7***	*Apis andreniformis* Smith, 1858	ĐN	27	1,5	13,9
8***	*Apis cerana* Fabricius, 1793	HCM, ĐN, TN	236	13,3	73,6
9***	*Apis dorsata* Fabricius, 1793	HCM, ĐN, TN	195	11	81,9
10***	*Apis florea* Fabricius, 1787	HCM, ĐN, TN	306	17,2	88,9
11***	*Apis mellifera* (Linnaeus, 1758)	HCM, ĐN, TN	110	6,2	40,3
I.3*	***Genus Bombus***				

12**	*Bombus eximius* Smith, 1852	ĐN	1	0,1	1,4
I.4	***Genus Homotrigona***				
13**,***	*Homotrigona apicalis* (Smith, 1857)	ĐN	20	1,1	9,7
14***	*Homotrigona fimbriata* (Smith, 1857)	ĐN	21	1,2	6,9
I.5	***Genus Lepidotrigona***				
15	*Lepidotrigona terminata* (Smith 1987)	HCM, ĐN, TN	26	1,5	11,1
I.6*	***Genus Lisotrigona***				
16**,***	*Lisotrigona cacciae* (Nurse, 1907)	ĐN	12	0,7	1,4
I.7	***Genus Tetragonula***				
17**,***	*Tetragonula collina* (Smith, 1857)	HCM, ĐN, TN	50	2,8	37,5
18***	*Tetragonula fuscobalteata* (Cameron, 1908)	HCM, ĐN, TN	39	2,2	11,1
19***	*Tetragonula pagdeni* (Schwarz, 1939)	HCM, ĐN, TN	34	1,9	23,6
I.8	***Genus Thyreus***				
20**	*Thyreus cyathiger* Lieftinck, 1962	HCM	1	0,1	1,4
21	*Thyreus himalajensis* (Radoszkowski, 1893)	HCM, ĐN, TN	42	2,4	36,1
22**	*Thyreus lilacinus* (Cockrell, 1919)	ĐN	2	0,1	2,8
23**	*Thyreus massuri* (Radoszkowski, 1893)	TN	1	0,1	1,4
II	**Subfamily Xylocopinae**				
II.1*	***Genus Braunsapis***				
24**	*Braunsapis clarihirta* Reyes, 1991	ĐN	1	0,1	1,4
25**	*Braunsapis cupulifera* (Vachal, 1895)	HCM, ĐN, TN	19	1,1	12,5
26**	*Braunsapis hewitti* (Cameron, 1908)	ĐN, TN	12	0,7	12,5
27**	*Braunsapis puangensis* (Cockerell, 1929)	ĐN, TN	3	0,2	4,2
II.3	***Genus Ceratina***				
28**	*Ceratina bryanti* Cockerell, 1919	ĐN	1	0,1	1,4
29**	*Ceratina cognata* Smith, 1879	HCM, ĐN, TN	12	0,7	8,3
30**	*Ceratina collusor* Cockerell, 1919	ĐN	3	0,2	4,2
31**	*Ceratina dentipes* Friese,1914	HCM, ĐN, TN	8	0,5	9,7

32	*Ceratina nigrolateralis* Cockerell, 1916	HCM, ĐN, TN	183	10,3	63,9
33	*Ceratina smaragdula* (Fabricius, 1787)	HCM, ĐN, TN	123	6,9	61,1
34[**]	*Ceratina sutepensis* Cockerell, 1929	TN	1	0,1	1,4
35[**]	*Ceratina unimaculata* Smith, 1879	HCM, ĐN	13	0,7	13,9
II.3	**Genus *Xylocopa***				
36[*,***]	*Xylocopa acutipennis* Smith, 1854	ĐN	1	0,1	1,4
37[***]	*Xylocopa aestuans* (Linnaeus, 1758)	HCM, ĐN, TN	30	1,7	23,6
38[***]	*Xylocopa caerulea* (Fabricius, 1804)	HCM, ĐN, TN	7	0,4	6,9
39[**,***]	*Xylocopa dejeanii* Lepeletier, 1841	ĐN	2	0,1	2,8
40[***]	*Xylocopa latipes* (Drury, 1773)	HCM, ĐN	29	1,6	16,7
41[***]	*Xylocopa minor* Maidl, 1912	HCM, ĐN, TN	81	4,6	37,5
42[***]	*Xylocopa nasalis* Westwood, 1838	HCM, ĐN, TN	32	1,8	19,4
43[**,***]	*Xylocopa phalothorax* Lepeletier, 1841	TN	1	0,1	1,4
44[**,***]	*Xylocopa ruficornis* Fabricius, 1804	HCM, ĐN	7	0,4	4,2
45[***]	*Xylocopa tenuiscapa* Westwood, 1840	HCM	4	0,2	4,2
	Total species		**45**		
	Total individuals		**1775**		

(Notes: * newly recorded species; ** genus/species newly added for Southeastern Vietnam; *** species of ecological/economic importance; HCM: Ho Chi Minh City; ĐN: Đong Nai Province; TN: Tay Ninh Province)

Within the recorded species, several rare taxa were identified. These include *Bombus* species, the black dwarf honey bee *Apis andreniformis*, the newly recorded *Xylocopa acutipennis*, and stingless bees newly documented in Dong Nai Province. In Ho Chi Minh City, species such as *Amegilla fimbriata*, *A. himalayensis*, *Thyreus cyathiger*, and *Xylocopa tenuiscapa* were found. In Tay Ninh Province, newly recorded species included *Thyreus massuri*, *Ceratina sutepensis*, and *Xylocopa phalothorax*. Species such as *Braunsapis hewitti*, *B. puangensis*, *Ceratina unimaculata*, and *Xylocopa ruficornis* were recorded in two of the three provinces. The remaining species were documented across all three provinces within the study area (Table 3.1).

Newly recorded species

This study provides the first record of *Xylocopa acutipennis* Smith, 1854 for the Apidae bee fauna of Vietnam. The species was discovered in natural forest habitat at elevations above 500 m in Bu Gia Map, Dong Nai Province. Previously, *X. acutipennis* had only been reported from Banglades, India, Myanmar, Nepal, and Pakistan, typically at elevations above 600 m. This research thus represents the first documentation of the species in Vietnam and in Southeast Asia. Studies also indicate that *X. acutipennis* is extremely rare, with very low numbers observed, for example, only one male and one female were recorded in Nepal, where the species was newly reported in 2016.

3.1.2 Economically valuable species

The study recorded 45 Apidae species in Southeastern Vietnam, none of which are currently listed in the IUCN Red List (2024) or the Vietnam Red Data Book (2007, 2025). However, regional studies show that stingless bees are experiencing sharp declines due to habitat loss and urbanization, highlighting their high conservation value. All recorded species play important ecological roles in pollination, with 22 species possessing economic value and application potential. Genera such as *Apis*, *Xylocopa*, *Homotrigona*, *Lepidotrigona*, *Lisotrigona*, and *Tetragonula* are particularly significant. Many species provide honey, wax, propolis, and other products of nutritional and medicinal value. Native species such as *Apis cerana* are widely domesticated, while stingless bees are increasingly cultivated due to their ease of management, safety, and economic benefits, contributing to pollination and sustainable agriculture. Carpenter bees (*Xylocopa*) also play an important role in crop pollination, enhancing agricultural productivity. However, increasing exploitation of carpenter bees for food and traditional medicine may negatively impact wild populations. This group has potential for pharmacological research, but scientific evidence remains limited, requiring further study and appropriate management.

3.1.3 Abundance and dominant species

Surveys recorded 1,775 individuals representing 45 species and 11 genera of Apidae bees in Southeastern Vietnam. The genus *Apis* was dominant, with 874 individuals, followed by *Ceratina* and *Xylocopa*, while

Bombus was represented by only one individual. *Apis florea* was the most abundant species, followed by *A. cerana*, *A. dorsata*, and *Ceratina nigrolateralis*, all of which were highly dominant in the study area.

3.1.4 Species richness estimation and frequency of occurrence

Chao 1 and Jacknife 1 analysis estimated approximately 55-58 species in the region, of which this study documented 77.6-81.8% of the potential species. Frequency of occurrence ranged from 1.4% to 88.9%, with *Apis florea* and *A. dorsata* being very common, while many other species appeared sporadically.

Overall, the Apidae bee fauna of Southeastern Vietnam is less diverse than that of northern Vietnam, but this study added three genera and 23 species, including one newly recorded species for Vietnam. The findings confirm the considerable diversity of stingless bees in Southeastern Vietnam.

3.2 Identification key to genera and species of apidae bees

1. On forewings, no transverse veins in the marginal cells.............….........8
   — On forewings, wing veins distinct …... 2
2. Hind tibia with corbicula (pollen basket); hind wings without jugal lobe...…....................................3
   — Hind tibia without corbicula or if present, not basket-shaped; hind wings with jugal lobe......…..4
3. Eyes hairy; hind legs with pads and without spurs …Genus *Apis* – 11
   — Eyes glabrous; no pads, hind tibia with spurs ....
   …...Genus *Bombus – B. eximius*
4. Forewings without stigma (Fig. 3.8a); first tarsal segment of mid and hind legs longer than tibia…..................................Genus *Xylocopa* – 15
   — Forewings with stigma; first tarsal segment of mid and hind legs shorter than tibia ....…...5
5. Abdomen without pygidial plate…..6
   — Abdomen with pygidial plate …..7
6. Forewings with two submarginal cells; basal labrum slightly constricted at basal pore…...Genus *Braunsapis* – 23
   — Forewings with three submarginal cells; basal labrum not constricted…...Genus *Ceratina* – 26
7. Apex of forewings with sparse hairs and coarse tubercles........................
   ....…Genus *Thyreus* – 33
   — Apex of forewings densely hairy, without tubercles............................
   …...Genus *Amegilla* – 36

8. Dorsal mesonotum margins surrounded by short dense hairs ....
…...Genus *Lepidotrigona* – *L. terminata*
— Dorsal mesonotum margins not surrounded by short dense hairs ...…9
9. Hind wings with 7–8 hamuli; body with yellow spots ....
....…Genus *Homotrigona* – 41
— Hind wings with 5–6 hamuli; body without yellow spots …..............10
10. Propodeum strongly projecting posteriorly, extending to metasomal tergites …..Genus *Tetragonula* – 42
— Propodeum not projecting posteriorly ....
…..Genus *Lisotrigona* – *L. cacciae*
11. Hind wing vein M extending beyond vein r-m ....…12
— Hind wing vein M not extending beyond vein r-m ....…13
12. Forewings transparent; propodeum yellow-brown …...............*A. cerana*
— Forewings dark brown; propodeum black ….........................*A. dorsata*
13. Propodeum black …..14
— Propodeum light brown ....*A. mellifera*
14. Tergites 1–2 black or reddish-brown basally…..............*A. andreniformis*
— Tergites 1–2 reddish-brown …..*A. florea*
15. Propodeum distinctly separated from posterior surface by a prominent ridge; posterior surface projecting ....…............................17
— Propodeum separated only by a fine line; posterior surface nearly horizontal, not projecting …..16
16. Mesonotum with black hairs …..*X. nasalis*
— Anterior and lateral mesonotum with white hairs …............*X. dejeanii*
17. Distance between compound eyes smaller at top than at bottom …........18
— Distance between compound eyes larger at top than at bottom …......19
18. Basal antennal segment flattened, broad at apex; third antennal segment shorter or equal to segments 4–6 ....…..........................*X. latipes*
— Basal antennal segment cylindrical; third antennal segment longer than segments 4–6 …...*X. tenuiscapa*
19. Mesonotum with blue or white hairs 20
— Mesonotum with yellow hairs 21
20. Mesonotum with blue hairs ....…*X. caerulea*
— Mesonotum with white hairs ....*X. phalothorax*
21. T1 with yellow hairs …..*X. ruficornis*
— T1 without yellow hairs 22
22. Vertex hairs yellow …...*X. minor*
— Vertex hairs black …..*X. aestuan*
23. Spots present near compound eyes; basal labrum entirely yellow; basal antennal segment yellow ventrally ....….......................*B. clarihirta*
— No spots near compound eyes …...24
24. Basal labrum entirely yellow with broad apical spot …..........................25
— Basal labrum black ventrally, apical spot narrow ….......*B. puangensis*

25. T4–6 hairs long, tapering …..*B. cupulifera*
— T4–6 hairs blunt-ended …..*B. hewitti*
26. Mesosoma separated from propodeum by a projecting ridge; body green or bronze ....…..27
— Mesosoma joined to propodeum by rounded ridge; body black or yellow …...28
27. Body metallic green, shiny; labrum spot truncated above, expanded below, margins concave; tubercles pale ….........................*C. smaragdula*
— Body bronze; labrum spot equilateral triangular, rounded above, margins straight; tubercles dark …..................................*C. unimaculata*
28. Head nearly circular in frontal view; small species, black, with straight white labrum stripe, white tubercles on pronotum and legs …..*C. dentipes*
— Head broader than high; larger species, yellow markings; labrum spot not straight stripe …..29
29. Mesonotum with yellow lines …..30
— Mesonotum without yellow lines; clypeus black, no yellow spots ....…*C. cognata*
30. Fore coxae angular, forming distinct tubercle …..................................31
— Fore coxae rounded, no tubercle …..32
31. Upper frons sparsely punctate; area between compound eyes and antennal sockets without punctures; basal antennal segment yellow …..*C. collusor*
— Upper frons densely punctate; basal antennal segment black ....
…...*C. nigrolateralis*
32. Pronotum with continuous yellow transverse band …................*C. bryanti*
— Pronotum with interrupted yellow transverse band …......*C. sutepensis*
33. Margins of T2–T3 with circular blue hair bands …..................*T. lilacinus*
— Blue hair bands on T2–T3 not circular …..34
34. Central band on T1 cup-shaped …..*T. cyathiger*
— Central band on T1 not cup-shaped …...35
35. Blue transverse band on T3 continuous …...............................*T. massuri*
— Blue transverse band on T3 divided into two unequal spots ....
…...*T. himalayensis*
36. Abdominal tergites with metallic blue hair bands …...............................39
— Abdominal tergites without metallic blue hair bands …....................37
37. All tergites with white apical hair bands …..............................*A. confusa*
— Tergites without white apical hair bands …..38
38. Facial and mesonotal hairs reddish-yellow …..................*A. himalayensis*
— Facial and mesonotal hairs white …..................................*A. fimbriata*
39. Mesonotal hairs gray-green; basal labrum with elongated black spots ......
…..*A. cingulata*
— Mesonotal hairs without gray-green color …......................................40

40. Mesonotal hairs reddish-brown; basal labrum with square black spots …..*A. zonata*
— Mesonotal hairs yellow-brown …...................................*A. calceifera*
41. Labrum short, width >2.5× length; wing apex light reddish-brown …...*H. fimbriata*
— Labrum width ~2× length; wing apex white …....................*H. apicalis*
42. Wing base different color, apex white; hind wings with 6 hamuli …..*T. collina*
— Wing base and apex same color; hind wings with 5 hamuli …..........43
43. Small body, <3.2 mm …..*T. fuscobalteata*
— Larger body, >3.2 mm …..*T. pagdeni*

3.3 Distributions of apidae bees

Floral resources are critical natural food sources for bees, providing nectar and pollen essential for growth and colony development. Nectar supplies basic energy in the form of sugars, while pollen contributes proteins, fats, vitamins, and minerals necessary for larval nutrition and nest construction. Thus, the composition of floral resources is one of the primary factors influencing the distribution of Apidae bees. In addition, habitat type and elevation also strongly affect their distribution.

3.3.1 Diversity of floral resources visiting by bees

Research in Southeastern Vietnam recorded 109 plant species from 46 families visited by Apidae bees, with a total of 1,320 individuals representing 41 bee species. Fabaceae and Asteraceae were the most important plant families, both in species richness and in attracting the highest numbers of bees. The lowest elevation zone attracted the highest numbers of bees. These findings emphasize the importance of conserving plant diversity and forest ecosystems, while promoting native vegetation in rural and urban landscapes to sustain pollinator communities.

3.3.2 Distribution by floral resources

Of the 1,775 Apidae individuals recorded, 1,320 individuals from 41 species, 10 genera, and 2 subfamilies were collected while visiting 109 plant species. Subfamily *Apinae* visited more plant species (85) than *Xylocopinae* (56). The genus *Apis* had the highest number of individuals visiting flowers (563 individuals across 67 plant species), followed by *Ceratina*, while *Lisotrigona* had the fewest. The red dwarf honey bee *Apis florea* was particularly prominent, with 214 individuals visiting 52 plant species, especially within Fabaceae and Asteraceae.

Regression analysis revealed strong correlations between the number of plant species and both bee species richness and abundance, confirming floral resources as a key determinant of bee diversity and density. Genera *Apis*, *Ceratina*, and *Xylocopa* showed the strongest interactions with Asteraceae, Fabaceae, Malvaceae, and Convolvulaceae. *Ceratina nigrolateralis* was closely associated with Asteraceae, while *Xylocopa minor* strongly interacted with Fabaceae. Plant species such as *Bidens pilosa*, *Chromolaena odorata*, *Mimosa pudica*, and *Celosia argentea* were major floral resources attracting the greatest diversity of bees. *Apis florea*, *A. cerana*, *A. dorsata*, *Ceratina nigrolateralis*, *C. smaragdula*, and *Xylocopa minor* were identified as key pollinators in Southeastern Vietnam.

3.3.3 Distribution by habitat

Surveys across three habitat types (natural forest, shrubland, residential areas) in Southeastern Vietnam recorded 45 Apidae species from 11 genera, totaling 1,775 individuals. Natural forests supported the highest species diversity (37 species), while shrublands had the largest number of individuals (661). Diversity indices (H’, D, J’) varied but showed no significant differences among habitats, indicating all three provide favorable conditions for bees. Species similarity among habitats was relatively high (67.8–81.3%), with natural forests more distinct, while shrublands and residential areas were more similar. Overall, natural forests harbored many rare species with low abundance, whereas shrublands and residential areas maintained high bee densities due to abundant floral resources.

3.3.4 Distribution by elevation

The distribution of bees in the family Apidae across elevational gradients in the Southeast Region of Vietnam revealed a total of 1,775 individuals belonging to 45 species and 11 genera, with bee abundance gradually decreasing with increasing elevation. The low-elevation zone (<50 m) exhibited the highest bee abundance (mean of 36.9 individuals per transect) and the highest Shannon–Wiener diversity index (H′ = 2.86), indicating favorable ecological conditions. In contrast, the high-elevation zone (>500 m) supported the greatest species richness (33 species) despite having a relatively low bee abundance (mean of 19.7 individuals per transect). This zone also harbored several rare and newly recorded species, including *Bombus eximius*, *Lisotrigona cacciae*, and *Xylocopa acutipennis*. Although the Margalef richness index (D) and Pielou's evenness index (J′) varied among elevational zones, the differences were not pronounced, suggesting a relatively even distribution of species across elevations. Nevertheless, low-elevation areas maintained higher bee abundance, whereas high-elevation habitats played a critical role in conserving species diversity.

3.3.5 Distribution in fruit orchards

Surveys in three fruit orchards at the foot of Bà Đen Mountain (Tây Ninh Province) recorded 628 individuals from 17 species, 6 genera, and 2 subfamilies. The genus *Amegilla* was the most diverse (5 species), followed by *Apis* and *Ceratina* (3 species each), with *Tetragonula*, *Thyreus*, and *Xylocopa* represented by 2 species each. Orchard M1 had the highest diversity and abundance (16 species, 350 individuals), followed by M2 (12 species, 200 individuals), and M3 (7 species, 78 individuals). *Ceratina* was dominant with 489 individuals, particularly *C. smaragdula* (368 individuals). One-way ANOVA indicated that orchard type significantly influenced both species richness and bee abundance. Diversity indices differed notably between M3 and the other two orchards. Species similarity grouped M1 and M2 together, while M3 was more distinct. Results demonstrate that maintaining plant diversity in fruit orchards supports bee diversity and enhances natural pollination services for sustainable agriculture.

3.4 Nest biology of apidae bees

3.4.1 Nesting sites of apidae bees

Surveys recorded nests of three native *Apis* species (*A. cerana*, *A. florea*, *A. dorsata*), except *A. andreniformis*, for which no nests were found. The introduced species *A. mellifera* was observed in managed colonies in rubber and cashew plantations in Dong Nai and Tay Ninh provinces. *A. cerana* nests were typically located in rock crevices, tree hollows, or under house roofs, whereas *A. dorsata* and *A. florea* built exposed nests on tree branches, cliffs, or artificial structures.

For stingless bees, 21 nests of six species from three genera (*Homotrigona*, *Lepidotrigona*, *Tetragonula*) were recorded, mostly on large tree trunks in natural forests. *Tetragonula collina* nested underground near tree bases, while *T. fuscobalteata* was found in urban parks. *Homotrigona fimbriata* nests were located at higher positions, with large and variable entrance structures.

Carpenter bees (*Xylocopa*) were observed nesting in fruit orchards, along canals, and near residential areas, typically in branches or dry stems of bamboo, fruit trees, or other woody plants. A total of 124 nests of four species (*X. minor*, *X. nasalis*, *X. ruficornis*, *X. latipes*) were collected and analyzed for nesting sites, nest structure, developmental stages, and surrounding floral resources. Surveys documented 45 plant species from 19 families associated with nesting sites and floral visitation. *Xylocopa* species most frequently visited Fabaceae and Asteraceae flowers, while Annonaceae, Moraceae, and Poaceae were commonly used as nesting substrates. *X. minor* visited the highest number of plant species (33), followed by *X. nasalis* (20), *X. latipes* (16), and *X. ruficornis* (12).

3.4.2 Nest biology of Xylocopa minor

Nests of *X. minor* were found in dry branches of trees such as *Annona*, *Ficus*, *Artocarpus*, and *Ficus microcarpa*, with 1–21 nests per tree. Nests were located 68–350 cm above ground, in branches averaging 43 cm long, with entrance diameters of ~4 cm. Each branch contained 1–5 nests, often near canals, riversides, and orchards. Entrances were circular, oriented downward, with tunnels excavated along the branch, unbranched, and smooth inside. Cells were constructed from the deepest part, partitioned with wood dust mixed with binding material. Development included four stages: egg (white, curved, 4.5 mm long), larva (19–21 mm), pupa (17–19 mm), and adult. *X. minor* visited 33 plant species from 16 families, most frequently Fabaceae (9 species), Asteraceae (5), and Malvaceae (3). Commonly visited flowers included *Cucumis melo*, *Benincasa hispida*, *Peltophorum pterocarpum*, *Canavalia cathartica*, *Bidens pilosa*, and *Senna alata*, highlighting its importance in crop and wild plant pollination.

3.4.3 Nest biology of Xylocop nasalis

Nests of *X. nasalis* were excavated in bamboo and reed stems in residential habitats, often near water and flowering plants. Nests were located 68–422 cm above ground, with circular entrances on the underside of stems, extending inward with cells at the deepest part. Partitions were thin, smooth, made of compressed bamboo dust. Development included four stages: egg (white, curved, 5.8–9.6 mm), larva (26–30 mm), pupa (21–24 mm), and adult. *X. nasalis* visited 20 plant species from 11 families, dominated by Fabaceae (7 species), followed by Asteraceae (3) and Cucurbitaceae (2). Frequently visited flowers included *Benincasa hispida*, *Melastoma malabathricum*, *Bauhinia purpurea*, *Lagerstroemia specios*, *Calotropis gigantea*, and *Canavalia cathartica*.

3.4.4 Nest biology of Xylocopa ruficornis

X. ruficornis nested in *Annona glabra* trees near orchards along canals. Nests were located 122–283 cm above ground, in branches averaging 47 cm long and ~23 mm in diameter, with 1–4 nests per branch. Entrances were circular, on the underside, with tunnels excavated along the branch, smooth inside, unbranched, and partitioned with thick wood dust walls. Development included four stages: egg (white, curved, 5.7 mm), larva (19 mm), pupa (17 mm), and adult. *X. ruficornis* visited 12 plant species from 7 families, dominated by Fabaceae (5 species) and Cucurbitaceae (2). Frequently visited flowers included *Bidens pilosa*, *Melastoma malabathricum*, *Lagerstroemia specios*, and *Canavalia cathartica*.

3.4.5 Nest biology of **Xylocopa latipes**

Nests of *X. latipes* were found in dry trunks of *Artocarpus heterophyllus* trees in orchards and gardens near canals, where many plants were flowering. Each tree contained 4–13 nests, located 82–333 cm above ground, with trunks averaging 258 cm long and entrance diameters of 12.6 cm. Entrances were oval, opening laterally, with winding tunnels, smooth inside, usually with a single entrance and 1–2 cells at the end. Development included four stages: egg 28–30 mm; adults 32.7 mm. *X. latipes* visited 16 plant species from 7 families, most frequently Fabaceae (7 species), followed by Myrtaceae (3) and Combretaceae (2).

CONCLUSION AND RECOMMENDATIONS

Conclusion

The present study on the family Apidae in the Southeast Region of Vietnam recorded 45 species belonging to 11 genera and 2 subfamilies, including one species newly recorded for the bee fauna of Vietnam and 23 species reported for the first time from the study region. The genus *Xylocopa* exhibited the highest species richness, whereas the genus *Apis* was the most abundant and dominant, with *Apis florea* being widely distributed across different habitats, elevational zones, fruit orchards, and flowering plant species. Natural forests, elevations above 500 m, and fruit orchards supported the highest species richness, while shrublands and low-elevation areas (<50 m) harbored the greatest bee abundance. This study also developed identification keys to both genus and species levels and documented 109 flowering plant species belonging to 46 families visited by bees, with Fabaceae and Asteraceae serving as the principal floral resources. Furthermore, the study provides the first records of nesting sites for species of *Apis*, stingless bees, and four *Xylocopa* species in the region, highlighting the diversity of bee nesting habitats in both natural forests and residential areas.

Recommendations

Although the study revealed a relatively rich bee fauna, it is clear that not all species in Southeastern Vietnam have been documented, particularly in extensive natural forests and among seasonally distributed species. Long-term surveys and investigations are therefore needed to build a more comprehensive biodiversity dataset for Apidae bees in the region.

This study provided the first dataset on floral resources and nest biology of many Apidae species, yet rare species with low abundance remain insufficiently represented, limiting understanding of bee–plant interactions. Further research is required on floral resources, pollinator–plant relationships, and nest biology, especially for native species in Southeastern Vietnam.

LIST OF THE PUBLICATIONS RELATED TO THE DISSERTATION

1. V T Le, U K Shimizu, V S Dang, T L Pham, and R Miyanaga, 2024. Evaluation of wild bee diversity in fruit orchards within the Ba Den mountain area, Tay Ninh Province, Vietnam. *IOPConference Series: Earth and Environmental Science* vol 1349 (2024) 012020: 1-9. DOI:10.1088/1755-1315/1349/1/012020 [Scopus].
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3. Le Van Tho, Dang Van Son, Pham Thanh Luu, Nguyen Quoc Bao, Pham Quoc Trong, Nguyen Thi Mai Huong, 2025. Bees (Hymenoptera, Apidae) and their floral preferences in an urban park, in Ho Chi Minh city. *National Biotechnology coference 2025*, pp. 210-216.
4. Le Van Tho, Pham Phong Huy, Dang Van Son, Pham Thanh Luu, Miyanaga R. 2026. First notes on the nesting biology of *Xylocopa minor* Maidl, 1912 (Hymenoptera: Apidae). *Russian Entomology Journal* Vol 35(1): 81–91. DOI: 10.15298/rusentj.35.1.04. [Scopus, Q2].
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6. Van Tho Le, Huy Phong Pham, Van Son Dang, Ryoichi Miyanaga, Thi Mai Huong Nguyen, Tran Vy Nguyen, Thanh Luu Pham, 2026. Nesting behavior and biology of two carpenter bees, *Xylocopa nasalis* and *Xylocopa ruficornis*, in Vietnam. *International Journal of Tropical Insect Science*. 1-15. https://doi.org/10.1007/s42690-026-01825-3 [SCIE, Q2].
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