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First notes on the nesting biology of *Xylocopa minor* Maidl, 1912 (Hymenoptera: Apidae)

Первые данные о гнездовой биологии *Xylocopa minor* Maidl, 1912 (Hymenoptera: Apidae)

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KEY WORDS: floral resources, large carpenter bee, nest architecture, Vietnam, *Xylocopa minor*.
КЛЮЧЕВЫЕ СЛОВА: floral resources, large carpenter bee, nest architecture, Vietnam, *Xylocopa minor*.

ABSTRACT. This study explores the nesting behaviour and plant preferences of the large carpenter bee *Xylocopa minor* Maidl, 1912 in Southeast Vietnam. The species primarily nested in dead wood branches of plant species, such as *Ficus benjamina* L., *Ficus elastic* Roxb. ex Hornem., *Artocarpus heterophyllus* Lam., and *Annona squamosal* L. The number of nests varied from 1 to 5 per branch and the nests were branched. *Xylocopa minor* excavated a round nest entrance on the underside of branches, usually at the middle of a nest, and made burrows in two opposite directions along the branch. There were from 2 to 11 cells per nest. Nest cells were separated by partitions made of the sawdust mixed with a glue. Most nests were maintained by 1–3 adult *X. minor* females. The only blister beetle, *Synhoria* sp. (Coleoptera: Meloidae), was recorded as a nest parasite of *X. minor*. The bee visited 33 flowering plant species from 31 genera and 16 families. The ecological significance of *X. minor* as an important pollinator of several plants, especially mangrove ones, is highlighted.

РЕЗЮМЕ. Исследована гнездовая биология и предпочтения растений крупной пчелы-плотника *Xylocopa minor* Maidl, 1912 в юго-восточном Вьетнаме. Пчелы гнездятся в мертвых ветвях таких древесных пород, как *Ficus benjamina* L., *Ficus elastic* Roxb. ex Hornem., *Artocarpus heterophyllus* Lam. и *Annona squamosal* L. Число гнезд варьирует от 1 до 5 на ветвь, и сами гнезда разветвлены. *Xylocopa minor* выкапывает округлый вход в гнездо на нижней стороне ветви, обычно в середине гнезда, и делает проходы в двух противоположных направлениях вдоль ветвей. Выявлено от 2 до 11 ячеек на гнездо. Ячейки разделены перегородками из опилок и глины. Большинство гнезд поддерживаются 1–3 взрослыми самками *X. minor*. Жук-майка *Synhoria* sp. (Coleoptera: Meloidae) был выявлен как гнездовой паразит *X. minor*. Пчелы посещали 33 вида цветковых растений из 31 рода и 16 семейств. Показано большое экологическое значение *X. minor* как опылителя, в частности, мангров.

Introduction

Large carpenter bees of the genus *Xylocopa* are among the most prominent and ecologically significant members of the family Apidae [Lucia *et al.*, 2015; He, Zhu, 2018; Buchmann, Minckley, 2019; Engel

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et al., 2020]. These bees play a crucial ecological role as pollinators for both wild and cultivated plants. Their adaptability, including plastic foraging habits, tolerance of high temperatures, and activity in low-light conditions, enhances their effectiveness as pollinators [Gerling *et al.*, 1989; Minckley, 1998; Michener, 2007; Ozbek, 2013].

Most *Xylocopa* species nest in dead wood structures, hollow stalks, and bamboo culms [Michener, 2007; Pham, 2022]. Two main nesting types known in these species of *Xylocopa* are the linear unbranched (straight chain) type, with the cells continuously distributed along the main burrow in hollow stalks and bamboo culms, and the linear branched type, with the cells continuously distributed along branched burrows in dead wood [Gerling *et al*., 1989]. The nest serves both as a shelter for adults and as a food storage location for the development of their offspring. Each offspring occupies one cell provisioned with both pollen and nectar. Cells are separated by partitions made of plant materials mixed with adult bees' slaver. Adult young bees emerging from nest cells have to perforate the partitions and exit the nest cells to the burrow and the nests from the nest entrance constructed by their parents. *Xylocopa* often reuse their old nests, especially species using bamboo culms for nesting sites [Hurd, Moure, 1960; Maeta *et al*., 1985; Hongjamrassilp, Warrit, 2014; Pham, 2022].

Although the nesting behaviour of *Xylocopa* has received a large number of studies in the world (for example Gerling *et al*. [1989]; Raju, Rao [2006]; Hannan *et al*. [2012]; Hongjamrassilp, Warrit [2014]; Lucia *et al*. [2015]; Ali *et al*. [2017]; Lucia *et al*. [2017]; He, Zhu [2020]), that remains limited in Vietnam, with the only study on *Xylocopa nasalis* Weswood, 1838 and *Xylocopa phalothorax* Lepeletier, 1841 being produced by Pham [2022]. In this study, we report the nesting behaviour of *Xylocopa minor* Maidl, 1912 in Vietnam for the first time.

Xylocopa minor belongs to the largest and most widespread subgenus, *Koptortosoma* Gribodo, 1894 in the genus *Xylocopa*. Although the species has been recorded in some countries in the Oriental region, such as India, Vietnam, Myanmar, Thailand, Laos, and Cambodia [Lieftinck, 1964; Hannan *et al*., 2012; Engel *et al.*, 2017; Ascher, Pickering, 2024], its biological data are so far unavailable. Based on findings on nesting sites, nest architecture, developmental stages, nest associates, and visited plants, this study aims to contribute to the knowledge of the nesting behaviour of *X. minor,* as well as of the genus *Xylocopa* in general, to clarify its role as a pollinator, and to have basic data for conservation of the species in ecosystems which this bee inhabits.

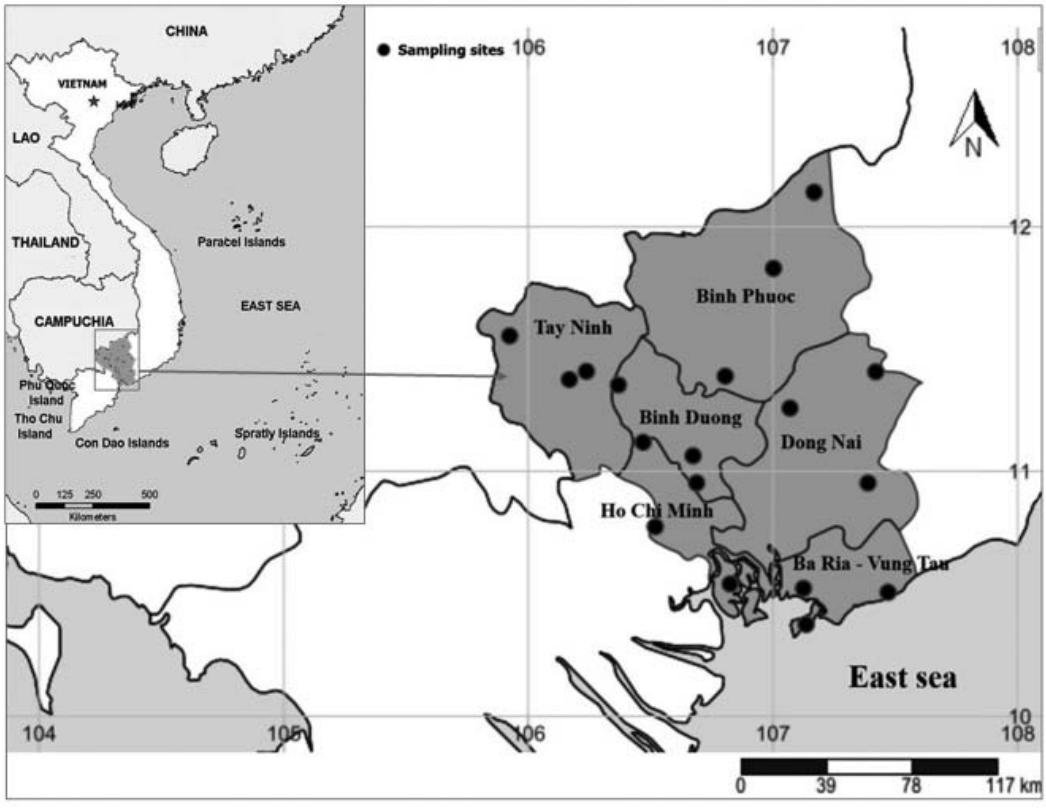

Fig. 1. Study areas for *Xylocopa minor* in Southeast Vietnam. Solid circles show locations surveyed.
Рис. 1. Местонахождения *Xylocopa minor* в юго-восточном Вьетнаме. Закрашенными кружками показаны изученные локации.

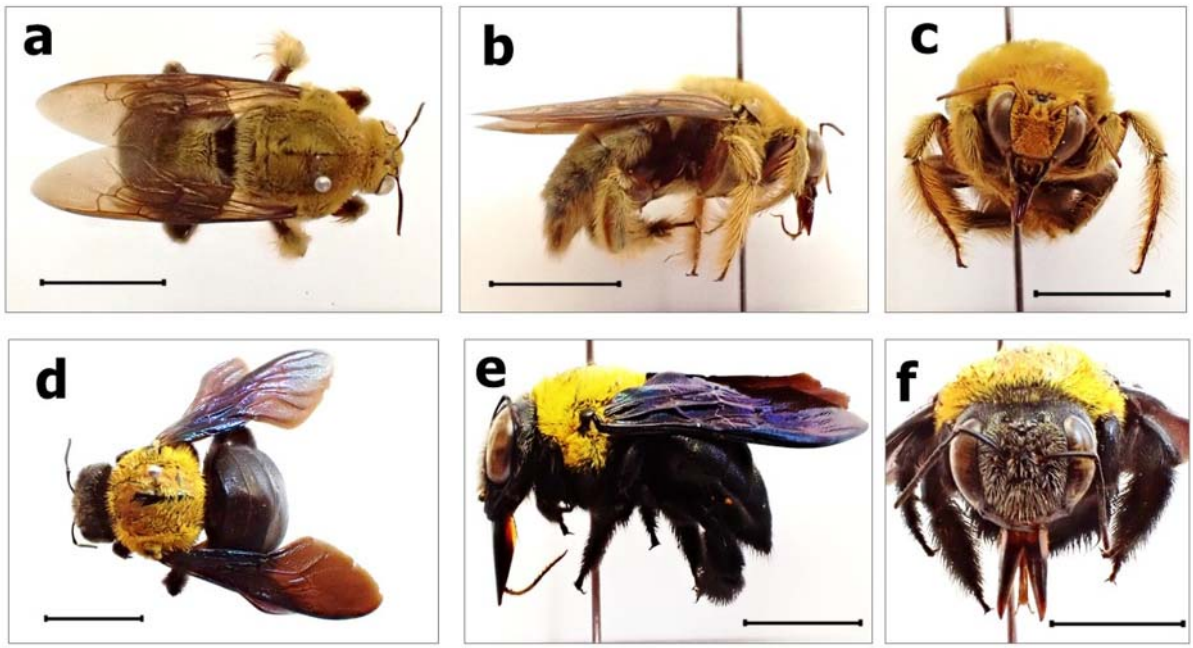

Fig. 2. External morphology of adult bees of *Xylocopa minor*. a–c — male, d–f — female; a, d — in dorsal view, b, e — in lateral view, c, f — in frontal view. Scale bars = 1 cm.
Рис. 2. Внешнее строение взрослых пчел *Xylocopa minor*. a–c — самец, d–f — самка; a, d — дорсально, b, e — латерально, c, f — фронтально. Масштаб 1 см.

Material and methods

Study areas and sampling

Field work was conducted between February 2023 and April 2025 at 18 locations in the following city and provinces in South Vietnam: Ho Chi Minh, Binh Duong, Binh Phuoc, Ba Ria -Vung Tau, Dong Nai, and Tay Ninh (Fig. 1). A total of 32 nests of *X. minor* were found and observed at five locations in three provinces, including Duong Minh Chau District and Tay Ninh City, Tay Ninh Province; Thuan An City and Thu Dau Mot City, Binh Duong Province; and Can Gio District, Ho Chi Minh City. These nests were collected for analyses of the nest structure in the laboratory. Before removing the nests, their nest entrances were sealed with toppers made of fine cloth to prevent adult bees from escaping.

Measurement and identification

The nests of *X. minor* were carefully dissected using a small saw and a knife. Adult bees presented in these nests were captured using insect nets and euthanized in containers charged with ethyl acetate. Measurements for nest-structural characteristics were minutely carried out using a stainless electronic caliper (150×0.01 mm). After the completion of checking and measurements, these nests were kept intactly in plastic boxes (40×25×20 cm). Images of the nests were taken using an OM System Tough TG-7 camera, providing detailed visual records of their architecture.

The adult bees collected from dissected nests were pinned, dried, identified with the aid of a Nikon SMZ745 stereomicroscope. The identification of *X. minor* was consistent with its original description and a re-description presented by Maidl [1912] and Lieftinck [1964], respectively. The female bee was characterized by having dense yellow hairs on the occiput, extending to the thorax and terminating in a straight line below the base of the fore wings; a low, narrow, impunctate median stripe on the clypeus; and wings with an incomplete first intercubitus (Fig. 2d–f). The male was distinguished by having yellow markings on the mandibles, clypeus, and supraclypeal area; dark brown antennae with their scape and first flagellomere yellow anteriorly, and the other flagellomeres likewise paler (orangish) anteriorly; and brownish wings with a complete first intercubitus and a weakly curved third intercubitus (Fig. 2a–c).

Plants around nesting sites of *X. minor* were carefully surveyed. As adult bees were found visiting flowers of any plants for feeding or foraging, we collected those plants for the identification. The plants were identified following Dang [2013], Dang *et al*. [2019], and Dinh [2021].

The specimens of both *X. minor* and plants examined in the present study are deposited in the Institute of Life Sciences, Vietnam Academy of Science and Technology, 85 Tran Quoc Toan Street, Xuan Hoa, Ho Chi Minh City, Vietnam.

Results

Nesting sites

Nests of *X. minor* were found being built into four dead plants: *Annona squamosal* L. (Fig. 3a)*, Artocarpus heterophyllus* Lam. (Fig. 3b), *Ficus elastic* Roxb. Ex Hornem. (Fig. 3c), and *Ficus benjamina* L. (Fig. 3d). The number of nests found in these plant species varied from 1 to 21 (n = 4). The nests were gone into branches that were 68.1–350 cm from the ground (mean 167.4 ± 80.2 cm, n = 19), 19.2–115.2 cm long (mean 43.3 ± 23.5 cm, n = 19), and 2.0–8.3 cm in diameter (mean 4.0 ± 1.7 cm, n = 19) (as measured

at nest entrances). The number of nests were 1–5 per branch (mean 1.7 ± 1.2 nests/branch, n = 19). The nests found were typically located in areas near water and floral sources, such as canal banks, riverbanks, and orchard gardens.

Nest architecture

Nest entrances were rather round, opened on the underside of branches downwards the ground surface and usually located at the central area of nest burrows

Fig. 3. Host plants of *Xylocopa minor* nests. a — *Annona squamosa;* b — *Artocarpus heterophyllus;* c — *Ficus elastic;* d — *Ficus benjamina.*
Рис. 3. Растения, на которых расположены гнезда *Xylocopa minor.* a — *Annona squamosa;* b — *Artocarpus heterophyllus;* c — *Ficus elastic;* d — *Ficus benjamina.*

Table 1. Measurements and contents of *Xylocopa minor* nests, n = 32.
Таблица 1. Промеры и содержимое гнезд *Xylocopa minor*, n = 32.

Nest characters	Minimum	Maximum	Mean ± SD
Burrow diameter (mm)	10.15	14.67	13.12 ± 1.06
Nest length (mm)	31.09	248.13	131.99 ± 47.75
Nest entrance diameter (mm)	9.49	14.9	11.14 ± 1.02
	9.87	15.23	11.72 ± 1.02
Cell length (mm)	16.38	24.92	21.27 ± 2.32
Cell width (mm)	11.07	16.66	13.60 ± 1.28
Thickness of partition (mm)	1.97	7.07	5.15 ± 1.33
Number of cells/nest	2	11	5.66 ± 2.25
Number of parental bees	1	4	1.19 ± 0.59
Number of mother bees	1	3	1.13 ± 0.42
Number of father bees	0	1	0.06 ± 0.25

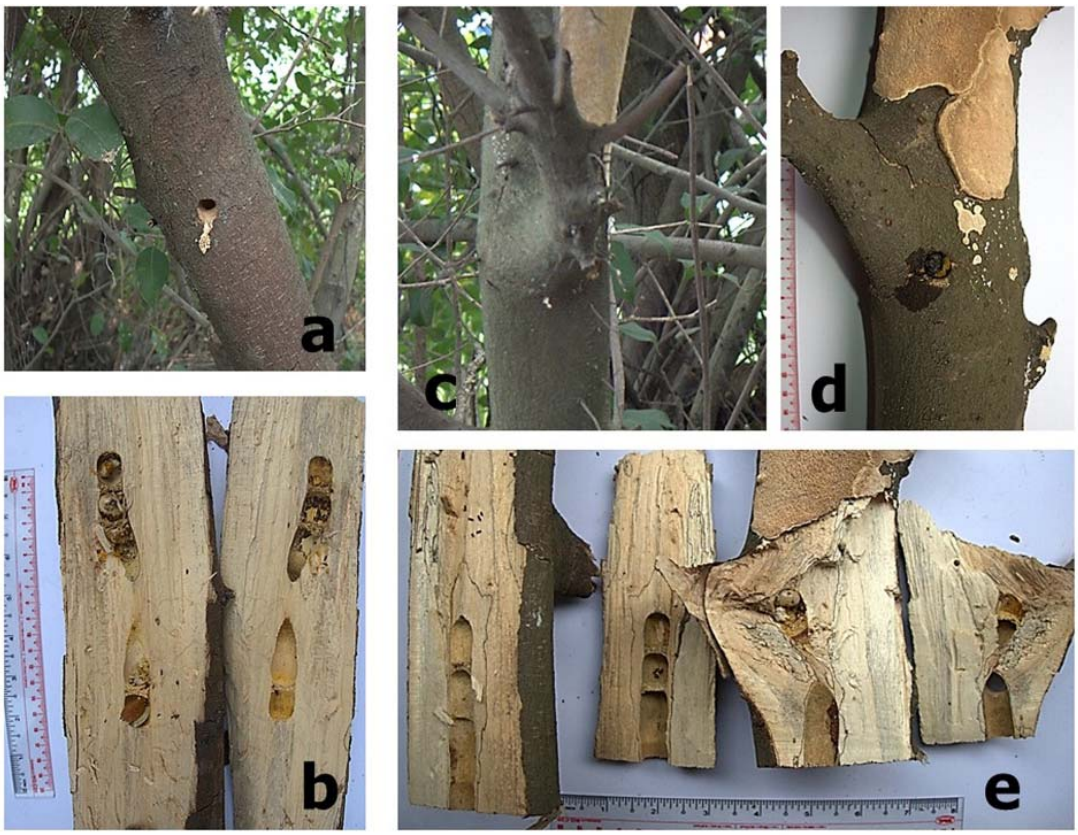

Fig. 4. Nests of *Xylocopa minor* in dead branches of *Ficus benjiamina*: a, c, d — positions of nest entrances; b, e — nest cells.
Рис. 4. Гнезда *Xylocopa minor* в мертвых ветвях *Ficus benjiamina*: a, c, d — расположение входа в гнездо; b, e — ячейки гнезда.

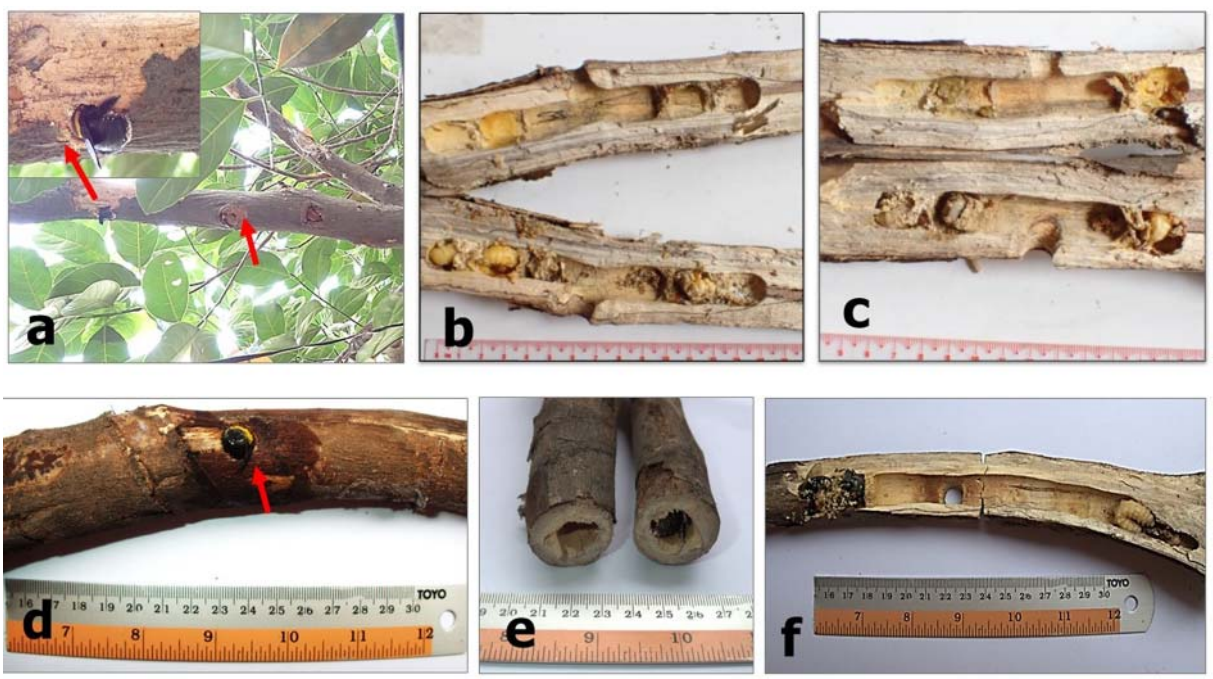

Fig. 5. Nests of *Xylocopa minor* in dead branches of *Artocarpus heterophyllus.* a, d — positions of nest entrances; b, c, e, f — nest burrow with cells. Arrows show the site of nest entrances.
Рис. 5. Гнезда *Xylocopa minor* в мертвых ветвях *Artocarpus heterophyllus.* a, d — расположение входа в гнездо; b, c, e, f — ходы гнезда с ячейками. Стрелками показано расположение входов в гнёзда.

Fig. 6. Nests of *Xylocopa minor* in dead branches of *Annona squamosa*: a, b, d — positions of nest entrances; c, e, f — nest burrows with cells.
Рис. 6. Гнезда *Xylocopa minor* в мертвых ветвях *Annona squamosa*: a, b, d — расположение входа в гнездо; c, e, f — ходы гнезда с ячейками.

(Figs 4a, c, d; 5a–d, f; 6a, b, d). These nest entrances were never closed and parental bees usually guarded there. The nest burrows were excavated along plant branches and moderately sinuous. The surface of burrows was rather smooth. The nests were branched and *X. minor* established its nest cells beginning from the innermost end of burrows (Figs 4b, e; 5b, c, e, f; 6c, e, f). Cell partitions were made of the sawdust, which was excavated out from shaving holes usually near the nest entrance, mixed with a glue that might be the bee's slaver. The partition was rather smooth and flat. Measurements of nest characters are showed in Table 1.

Developmental stages

Xylocopa minor had four developmental stages, including egg, larva, pupa, and adult. The egg was white, conspicuously curved, 4.5 mm long and 1.8 mm in diameter (n = 1), and glued to food at its one end (Fig. 7a). The larva was opalescent and it consumed all provisions stored in the nest cell (Fig. 7b). The full developmental larva was 19.2–21.1 mm long (n = 2). The pupa was milky white at the initial time of pupation (Fig. 7c) and 17.2–18.8 mm long (n = 2). First adult bees merged from cells located near the nest entrance. Emerging adult bees chewed out the partition and exited the nest at the nest entrance (Fig. 7d).

Nest parasite

We recorded three adults of a nest parasite *Synhoria* sp. of the family Meloidae (Coleoptera) (Fig. 8a–d) in two nests of *X. minor*, one with one adult and one with two adults.

Foraging

Xylocopa minor was recorded visiting 33 plant species across 31 genera and 16 families (Table 2, Figs 9a–f; 10a–h). The family Fabaceae was the most frequently visited plants, with nine species, following by Asteraceae with five species and Malvaceae with three species.

We minutely investigated plants near the nesting area and found several *X. minor* adults foraging usually on *Luffa cylindrical* (L.) M. Roem, *Benincasa hispida* Cogn., *Peltophorum pterocarpum* (DC.) Backer ex K. Heyne, *Canavalia cathartica* Thouars, *Bidens pilosa* L., and *Senna alata* (L.) Roxb. (Fig. 9a–f).

Discussion

Xylocopa minor uses dead wooden substrates for its nesting that is similar to several other bee species in the genus *Xylocopa*, for example, *Xylocopa pubescens* Spinola, 1838 and *X. fenestrata* (Fabricius, 1798) (see Ali *et al*. [2017]), *X. latipes* (Drury, 1773) and *X. pubescens* [see Raju, Rao, 2006], *X. sulcatipes* Maa, 1970 and *X. pubescens* (see Gerling *et al*. [1989]), *X. sulcatipes* (see Hannan *et al*. [2012]), *X. valga* Gerstäcker, 1872 (see He, Zhu [2020]), and *X. phalothorax* (see Pham [2022]). During the study time, we recorded living bamboo thickets and fences very near nesting sites of *X. minor*, but no nests were built into these substrates. This indicates that the bee favourably constructs its nests only within dead

Table 2. Flowering plants visited by *Xylocopa minor* in Southeast Vietnam.
Таблица 2. Цветущие растения, которых посещает *Xylocopa minor* в юго-восточном Вьетнаме.

No.	Family	Genus	Species	Number of bee individuals recorded
1	**ACANTHACEAE**	*Acanthus*	*Acanthus ilicifolius* L.	3
2	**APOCYNACEAE**	*Calotropis*	*Calotropis gigantea* (L.) W.T. Aiton	3
3	**ASTERACEAE**	*Bidens*	*Bidens pilosa* L.	6
4		*Chromolaena*	*Chromolaena odorata* (L.) R.M. King & H. Rob.	5
5		*Gymnanthemum*	*Gymnanthemum amygdalinum* (Delile) Sch. Bip.	2
6		*Pluchea*	*Pluchea indica* (L.) Less.	3
7		*Wollastonia*	*Wollastonia biflora* (L.) DC.	3
8	**BIGNONIACEAE**	*Tecoma*	*Tecoma stans* (L.) Juss. ex Kunth	2
9	**COMBRETACEAE**	*Lumnitzera*	*Lumnitzera littorea* (Jack) Voigt	4
10			*Lumnitzera racemosa* Willd.	3
11	**CONVOLVULACEAE**	*Ipomoea*	*Ipomoea pes-caprae* (L.) R. Br.	1
12	**CUCURBITACEAE**	*Benincasa*	*Benincasa hispida* Cogn.	4
13		*Luffa*	*Luffa cylindrica* (L.) M. Roem	2
14	**FABACEAE**	*Aeschynomene*	*Aeschynomene americana* L.	2
15		*Bauhinia*	*Bauhinia purpurea* L.	2
16		*Canavalia*	*Canavalia cathartica* Thouars	6
17		*Centrosema*	*Centrosema pubescens* Benth.	6
18		*Crotalaria*	*Crotalaria pallida* Aiton	1
19		*Mimosa*	*Mimosa pudica* L.	4
20		*Peltophorum*	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne	10
21		*Senna*	*Senna alata* (L.) Roxb.	8
22			*Senna occidentalis* (L.) Link	1
23	**LAMIACEAE**	*Hyptis*	*Hyptis suaveolens* (L.) Kuntze	1
24		*Vitax*	*Vitex pinnata* L.	2
25	**LYTHRACEAE**	*Lagerstroemia*	*Lagerstroemia specios* (L.) Pers.	1
26	**MALVACEAE**	*Abutilon*	*Abutilon indicum* (L.) Sweet	6
27		*Thespesia*	*Thespesia populnea* (L.) Soland. ex Correa	1
28		*Waltheria*	*Waltheria indica* L.	3
29	**MARANTACEAE**	*Thalia*	*Thalia geniculata* L.	3
30	**MELASTOMATACEAE**	*Melastoma*	*Melastoma malabathricum* L.	3
31	**MYRTACEAE**	*Syzygium*	*Syzygium samarangense* (Blume) Merr. & L.M. Perry	2
32	**PASSIFLORACEAE**	*Turnera*	*Turnera subulate* Sm.	1
33	**SOLANACEAE**	*Solanum*	*Solanum torvum* Swartz	2
Total	**16**	**31**	**33**	**106**

wooden substrates. *Xylocopa minor* built many nests very close together on the same branch suggesting that the bee nests aggregately. The nest aggregation at the same site is reported not only for *Xylocopa* (for example, *Xylocopa xinjiangensis* (Wu, 1983), see He, Zhu [2018]) but also for many other bees and wasps, especially ground-nesting wasps (for example, *Sphex ichneumoneus* (Linnaeus, 1758), see Brockmann [1979] or *Sphecius grandis* (Say, 1823), see Hastings [1986]). An aggregative nesting can probably counterbalance the costs of increased intraspecific competition and pathogen transmission, help other individuals to find a cue to locate suitable nesting sites, promote increased foraging efficiency and confer improved protection from predators or parasites [Rosenheim, 1990; Pham 2024]. In the case of *X. minor*, it is clear that the last benefit is confirmed as the only parasite, *Synhoria* sp., was found in two of 32 nests collected, while the other speculative benefits need to be further studied.

The genus *Xylocopa* has been documented as hosts and vectors of various blister beetles of the family Meloidea. For example, *Synhoria testacea* (Fabricius, 1801) has been recorded laying its eggs in nest cells of *Xylocopa capiata* (Smith, 1854) in South Africa [Bologna, Laurenzi, 1994]. *Xylocopa* are also considered as potential hosts for *Synhoria maxillosa* (Fabricius, 1801) in Thailand [Hawkeswood, Sommung, 2018]. Bologna and Pinto [2002], Bologna *et al*. [2013], and Ghoneim [2013] record about 30 species of *Xylocopa* as hosts and vectors of meloid parasites of the genera *Cissites*, *Horia*, and *Synhoria*. Thus, it is not surprising that *Synhoria* sp. presents in *X. minor* nests, but its parasitic strategy remains unknown and needs to be clarified, taking into account that *X. minor* adults always live in their nests.

Although *Xylocopa* are generally polylectic, with highly variable host plants, Fabaceae, Asteraceae, and Lamiaceae are often preferred [Terzo *et al*., 2007]. In the present study, we found that two families, Fabaceae and Asteraceae, were the most diverse plants in study areas and the most common plants visited by *X. minor*. *Xylocopa iris* (Christ, 1791), an unbranched nester, exhibits a preference for Fabaceae and Lamiaceae plants

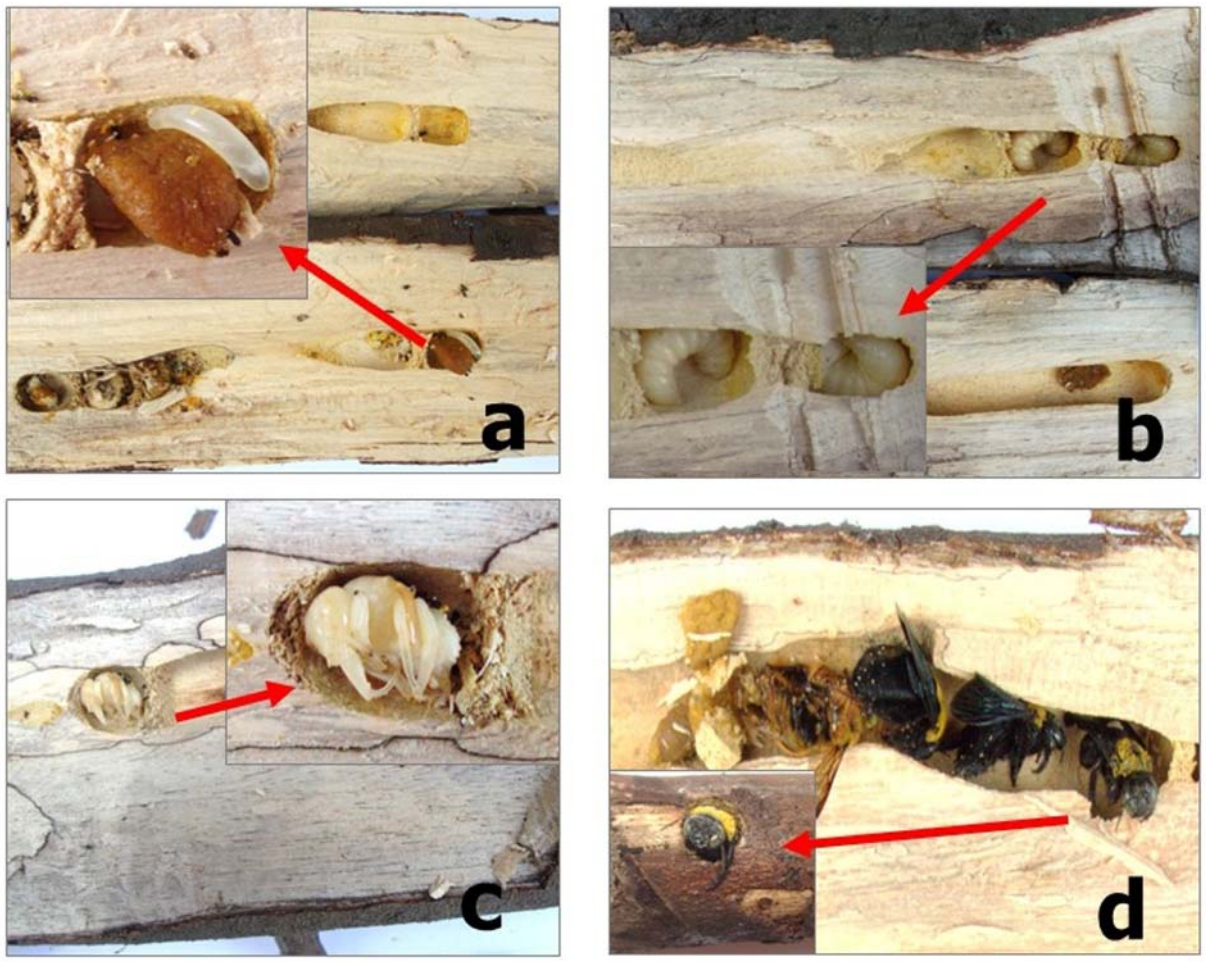

Fig. 7. Developmental stages (arrowed) of *Xylocopa minor*. a — egg; b — larva; c — pupa; d — adult.
Рис. 7. Стадии развития (показаны стредками) *Xylocopa minor*. a — яйцо; b — личинка; c — куколка; d — взрослая особь. Arrows show developmental stages.

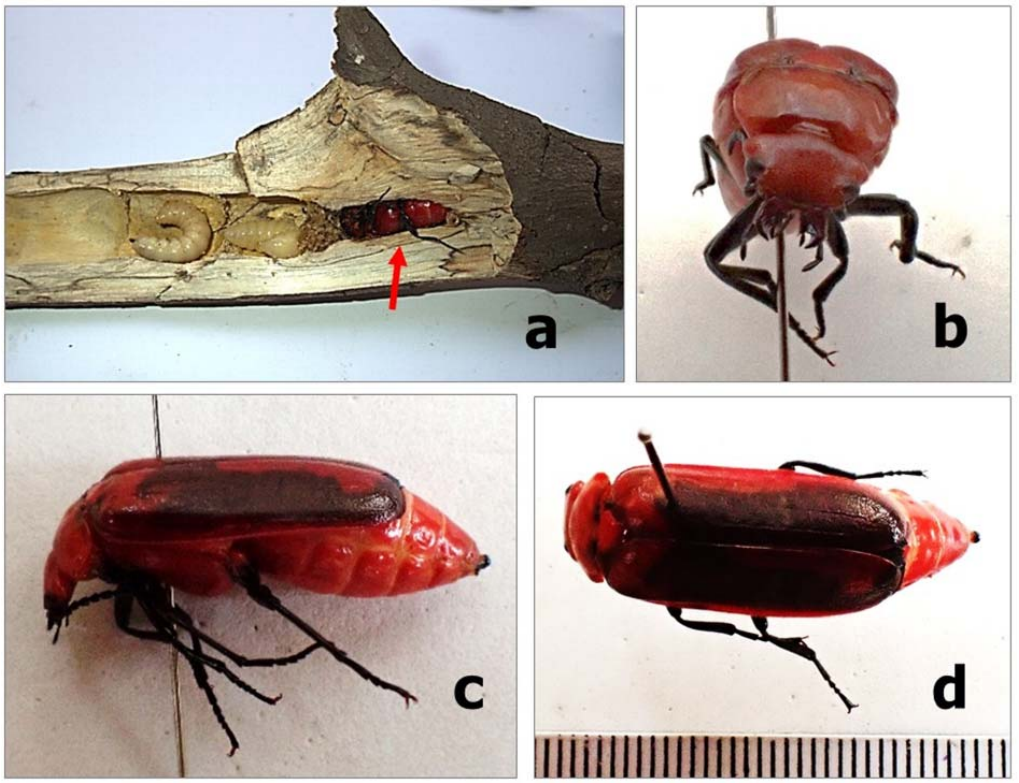

Fig. 8. The parasite *Synhoria* sp. found in a nest of *Xylocopa minor*. a — adult parasite in the innermost cell; b–d — external morphology of *Synhoria* sp., b — in frontal view; c — in lateral view; d — in dorsal view.
Рис. 8. Паразит *Synhoria* sp., обнаруженный в гнезде *Xylocopa minor*. a — взрослый паразит во внутренней ячейке; b–d — наружное строение *Synhoria* sp., b — фронтально; c — латерально; d — дорсально.

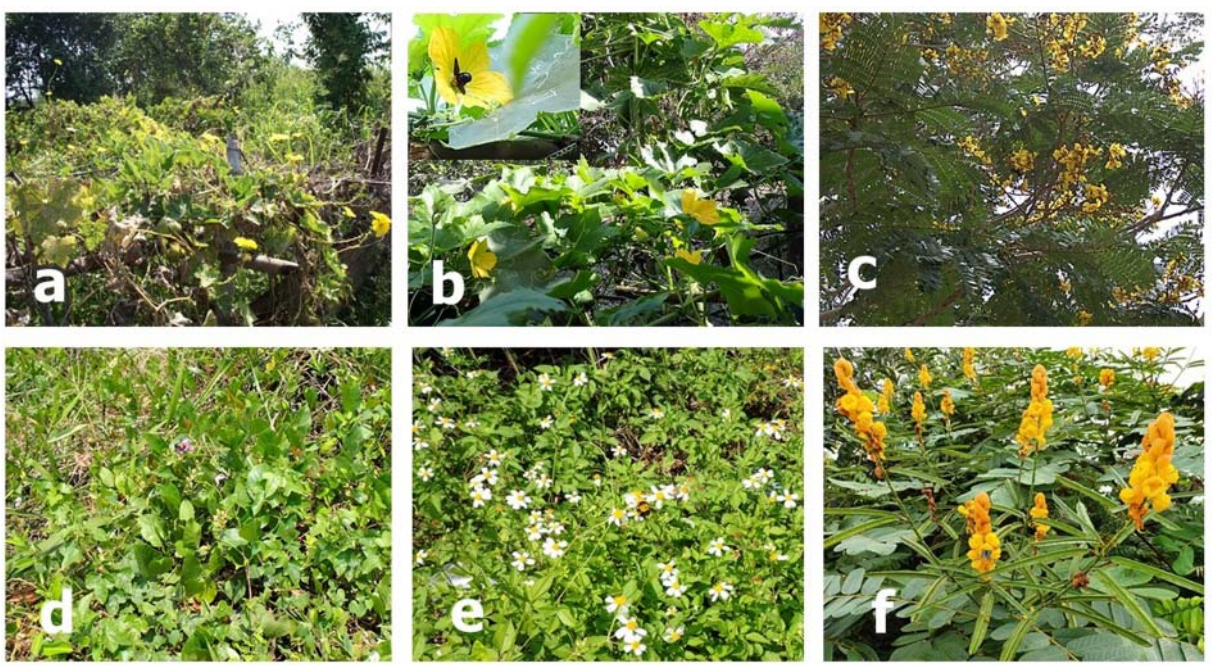

Fig. 9. Forage plants of *Xylocopa minor* near its nest area. a — *Luffa cylindrica*; b — *Benincasa hispida*; c — *Peltophorum pterocarpum;* d — *Canavalia cathartica;* e — *Bidens pilosa*; f — *Senna alata.*
Рис. 9. Фуражировочные растения около гнезд *Xylocopa minor*. a — *Luffa cylindrica*; b — *Benincasa hispida*; c — *Peltophorum pterocarpum;* d — *Canavalia cathartica;* e — *Bidens pilosa*; f — *Senna alata.*

Fig. 10. *Xylocopa minor* visiting flowering plants in mangrove habitats. a — *Lumnitzera littorea;* b — *Lumnitzera racemosa*; c — *Acanthus ilicifolius*; d — *Thespesia populnea*; e — *Canavalia cathartica*; f — *Aeschynomene americana*; g — *Wollastonia biflora*; h — *Pluchea indica.*
Рис. 10. *Xylocopa minor*, посещающая цветущие растения в манграх. a — *Lumnitzera littorea;* b — *Lumnitzera racemosa*; c — *Acanthus ilicifolius*; d — *Thespesia populnea*; e — *Canavalia cathartica*; f — *Aeschynomene americana*; g — *Wollastonia biflora*; h — *Pluchea indica.*

in Turkey [Daser-Özgisi *et al.*, 2023]. Here, our findings showed 16 host families suggesting that *X. minor* has a polylectic foraging behavior and its larval diet choices may be more specialized.

Xylocopa minor was recorded visiting several mangrove plants such as *Lumnitzera littorea, Lumnitzera racemosa, Acanthus ilicifolius, Thespesia populnea, Canavalia cathartica, Aeschynomene americana, Wollastonia biflora,* and *Pluchea indica.* The adaptability of *X. minor* to mangrove ecosystems significantly contributes to the mangrove pollination network, especially to the conservation of the first species as it is listed in the IUCN Red List [Ellison *et al*., 2010] as LC (Least Concern) and in the Vietnam Red Book [MST, VAST, 2007] as VU (Vulnerable) [Quach, Nguyen, 2021].

A wide distribution of *Xylocopa* is influenced by factors such as environmental conditions, habitat availability, floral resources, and suitable nesting sites [He, Zhu, 2020]. In Southeast Vietnam, the primary nesting sites for *X. minor* to be commonly grown fruit trees such as jackfruit and custard apple, common plants for the bee visiting such as *Bidens pilosa* which is widely distributed and blooming year-round, and winter unavailable suggest that the population of *X. minor* is often abundant and the carpenter bee possibly has more than one generation in year.

Conflict of interest. The authors declare no competing interests.

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