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Large Carpenter Bees in Thailand and Biology of *Xylocopa nasalis* (Westwood)

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ABSTRAC.- Large carpenter bees from various localities in the Kingdom of Thailand were collected, classified and investigated together with those from local collections. A total of 11 species were identified, namely *Xylocopa latipes* Drury, *X. tenuiscapa* Westwood, *X. nasalis* Westwood, *X. tranquebarica* Fabricius, *X. rufescens* Smith, *X. caerulea* Fabricius., *X. abbotti* Cockerell, *X. aestuans* Linnaeus, *X. verticalis* Lepel, *X. collalis* Lepel and *X. basalis* Smith.

The complexity of social life of *Xylocopa* spp. was found in their lifespan. At the outset they lead a solitary life and then enter into subsocial and quasisocial systems respectively. Twenty of the *X. nasalisí* buit-in bamboo nests at Kamphaengsaen Campus were investigated. The number of larval and pupal cells were found ranged between 3-15 cells per nest. The intermediate stage which active form may be called "subimmago", was the first time recorded between pupa and adult stage. The sex ratio of male and female per nest was 1:4. The parasitic larvae of *Ophelimus* sp. (Family Eulophidae) and the predator larvae of *Cissites maxillosa* (Family Meloidae) were also found in the nest.

Large carpenter bees spent large amounts of time in the nest guarding against the intrusion of ants *Camponotus* (*Tanaemyrmex*) sp. (Family Formicidae) . The female carpenter bee would position herself very near the entrance, clinging to the top of the tunnel wall and would block the nest entrance with her abdomen

KEYWORD.- Large carpenter bees, *Xylocopa nasalis*, Biology, Thailand

INTRODUCTION

Large carpenter bees (*Xylocopa* spp.) are insect pollinators that are crucial for the agriculture due to their effective roles for pollination. Classified in the Order Hymenoptera, Family Apidae, Suborder Xylocopinae, Tribe Xylocopini, Genus *Xylocopa*. (Root, 1950) Giant carpenter bees or large carpenter bee, as suggested by their common name, possess large body size and powerful mandibles that are able to bite and drill through various kinds of wood, such as bamboo, pine, or dried wood, to establish entrances to the nest for brooding. (Hurd and Moure, 1960) These holes or entrancesalso emit undesirable, strong goat-like odor.

Large carpenter bees are the largest and most strongest bees of the world. (Essig, 1954) From its size and shape, large carpenter bees can often times be mistaken form bumble bees, which possess large bodies and are categorized in the Genus *Bombus*, Tribe Bombini,

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Subfamily Apinae, Family Apidae. A major distinction between the large carpenter bee and the bumble bee can be found in the body of the carpenter bee that has shiny and illustrious gaster, which display most hair on the peripheral rather than on the actual body. Furthermore, the hind tibia of the female bumble bee has been specifically developed to serve as the pollen basket or corbicula.

Large carpenter bees number about approximately 730 species, found mostly in tropical zones and warm climate areas. (Michener, 2000) Species of the carpenter bees can be found in various parts of Thailand. In general, their body color range from shiny-black or brown, while their body hair display cerulean blue or yellow in color. When carpenter bees gather nectar or pollen for food by visiting the flower, they accumulate pollen grains that adhere to their hair in the process. Through their foraging behavior, carpenter bees attempt visits to various flower species in the same trip, which cause a transfer of pollen grains from the one flower species to the other, resulting in a cross-breeding fertilization. The shape and size of carpenter bees enable them to perform effective pollination with large flower species, such as *Plassiflora edulis* Sims (Family Passifloraceae) and *Ipomoea aquatica* Forsk (Family Convolvulaceae) as well as accommodate their tripping with large size of papillionate flower of legume type, such as *Vigna unguiculata* L. (Family Papilionaceae). Another prominent characteristic of these bees is their frequent and active flower visits that trigger an increase in the yield crop. The species known as *X. tranquebarica* is a nocturnal pollinator by nature, which assist in the pollination of flowers that bloom in the night.

MATERIALS AND METHODS

Specimens of adult carpenter bees were collected from various parts of Thailand during 1999-2005, while a specimen collection was also obtained from various insect museums such as Department of Agriculture, Ministry of Agriculture and Cooperative , Department of Entomology, Faculty of Agriculture, Kasetsart University, Museum of Deprtment of Pest Management Faculty of Natural Resource, University of Songklanakarin and the Department of Entomology, Faculty of Agriculture, Changmai University.

1. General external morphology of large carpenter bees was found in Thailand. A stereo zoom microscope was used to observe both male and female bees, measure their sizes and identify their major characteristics as well as species.

2. Preliminary biological study of the *Xylocopa nasalis* carpenter bees during August 2001 ñ August 2002, 20 nests were gathered and observed with regards to their behavior and development up until their entry into the adult stage. During observation, bamboo stems were slit, covered with black paper and tightened using adhesive tape. The stems would be opened daily to checkup on the brooding development as well as activities within the nest. For the subimmago, or intermediate stage (before adult offspring), the bees also had to be manually feed using honey on a daily basis.

RESULTS

1. General external morphology of large carpenter bees have been found in Thailand

External Morphology of Carpenter Bees (Figure 1)

Large carpenter bees generally possess a body size of 1.25-3.50 cm. in length and body color ranging from black, reddish brown, brown, cerulean blue, white, to yellow. Their round head consists of large compound eyes, especially for the male, three simple eyes, and antennae of the geniculate type (13 segments for male, 12 segments for female). Some carpenter bee species contain expandable scapes whose second stem or pedicel is relatively small, while their remaining stems in the flagellum are cylindrically shaped. Carpenter bees possess short and strong mandibles with countable two-three jagged teeth, smaller for male than the female. Their maxiliary palpi consists of 6 stems, the first three of which are large and elongated, while the remaining three are usually narrow and

short. The hair-covered stripe, for some species, can be used for sanitation purposes as well for pollen collection. In addition, their strong galea resembles a shell that is elongated with a sharp tip for protection as well as penetration into the flowerís collora. The labial palpi consists of 4 stems, the first 2 of which are long while its remaining are shorter in length. Some species of the male contain a slight yellow pubescent feature that is different from the female.

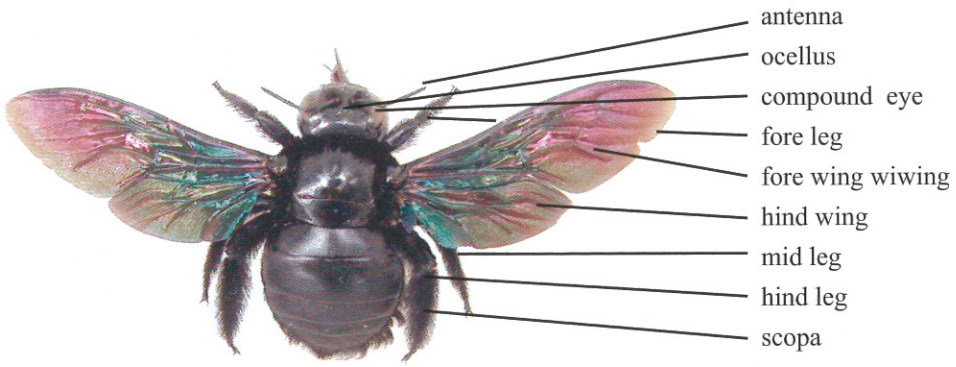


Figure 1 General Structure of the Large Carpenter Bee

Carpenter bees contain two pairs of narrowed, triangular-shaped wings that are larger in the fore wings than the hind wings. These wings display an opaque lustrous blue on its membrane, while also emitting a spectrum of colors. Certain species of carpenter bees exhibit light-brown membranes with dark brown wing venation. The fore wings consist of 3 submarginal cells, whose second submarginal cells resemble a triangle. In addition, no stigma exists, while their radial cell is elongated. Furthermore, their hind wings are without an anal lobe [Figure 2]. The tibia and basitarsi of the hind legs are expanded and consist of numerous pubescent called scopal hair on female carpenter bees for collecting pollen.

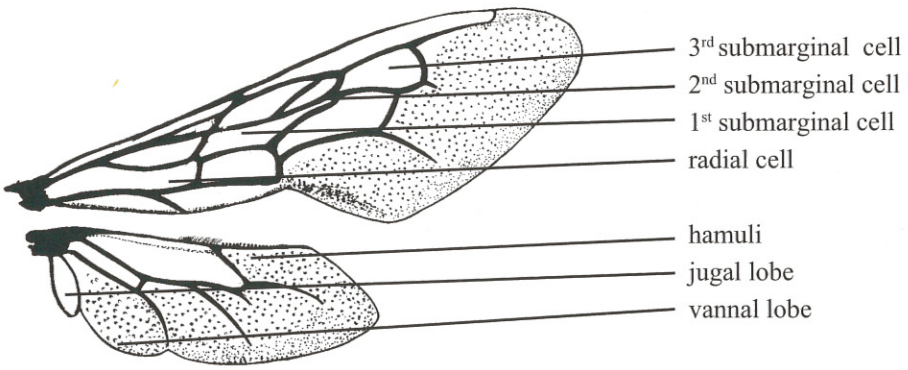


Figure 2 External morphology wing venation of large carpenter bees.

From this study, 11 species of large carpenter bees (Figure 3.1 and 3.2) as follows: *Xylocopa* latipes Drury, *X. tenuiscapa* Westwood, *X. nasalis* Westwood, *X. tranquebarica* Fabricius, *X. rufescens* Smith, *X. caerulea* Fabricius, *X. abbotti* Cockerell, *X. aestuans* Linnaeus, *X. verticalis* Lepel, *X. collalis* Lepel and *X. basalis* Smith are able to be classified by various sizes.

Ranging from 18-35 mm into the following three categories:

1. Large size of 30-35 mm in length include : *X.latipes* and *X. tenuiscapa*
2. Moderate size of 21-29 mm in length include : *X. tranquebarica*, *X. rufescens*, *X. aestuans*, *X. caerulea* and *X. nasalis*
3. Small size of 18-20 mm in length include : *X. abbotti*, *X. basalis*, *X. collalis* and *X. verticalis*

Pubescent color distinction on thorax - Plumose-type pubescent covering the thorax for pollen collection. Species identification by determining the distinct pubescent color on the thorax:

1. Black include : *X. latipes*, *X. tenuiscapa* and *X. nasalis*
2. Reddish-brown include : *X. rufescens* and *X. tranquebarica*
3. Yellow include : *X. aestuans* and *X. verticalis*
4. Blue include : *X. caerulea* and *X. abbotti*
5. White include : *X. collalis* and *X. basalis*

Head characteristic ñ Clypeus-type in some male with yellow pubescent for *X. tranquebarica*, *X. nasalis* and *X. rufescens*

Compound eye characteristic ñ Large-type in some male, expanded to maximum capacity for *X. latipes* and *X. tenuiscapa*

Wing characteristic ñ Opaque, spectrum-emitting luminosity characteristics found in : *X.latipes, X. tenuiscapa* and *X. nasalis*, and transparent light-brown characteristic found in *X. rufescens* and *X. tranquebarica*

Fore leg in male ñ Tibia and tarsus are expanded with long pubescent for catching the female during mating process. These are found in : *X .latipes* and *X. tenuiscapa*

2. Preliminary biological study of the Xylocopa nasalis

Studies of species and location of nests found in plants revealed that carpenter bees preferred to establish their nests in bamboo wood and deceased kapok wood, whose opening was measured at an elevation of 150-200 cm from ground level. From the study of 20 *X. nasalis* nests during August 2001 - August 2002, the bees chose to establish their habitation within the stem of the bamboo that has an internode length of approximately 32.63 cm and an internal diameter of 1.56 cm. The opening was measured at approximately 1.18 cm horizontally and 1.35 cm vertically. The average ratio of male to female was found to be 1:4.

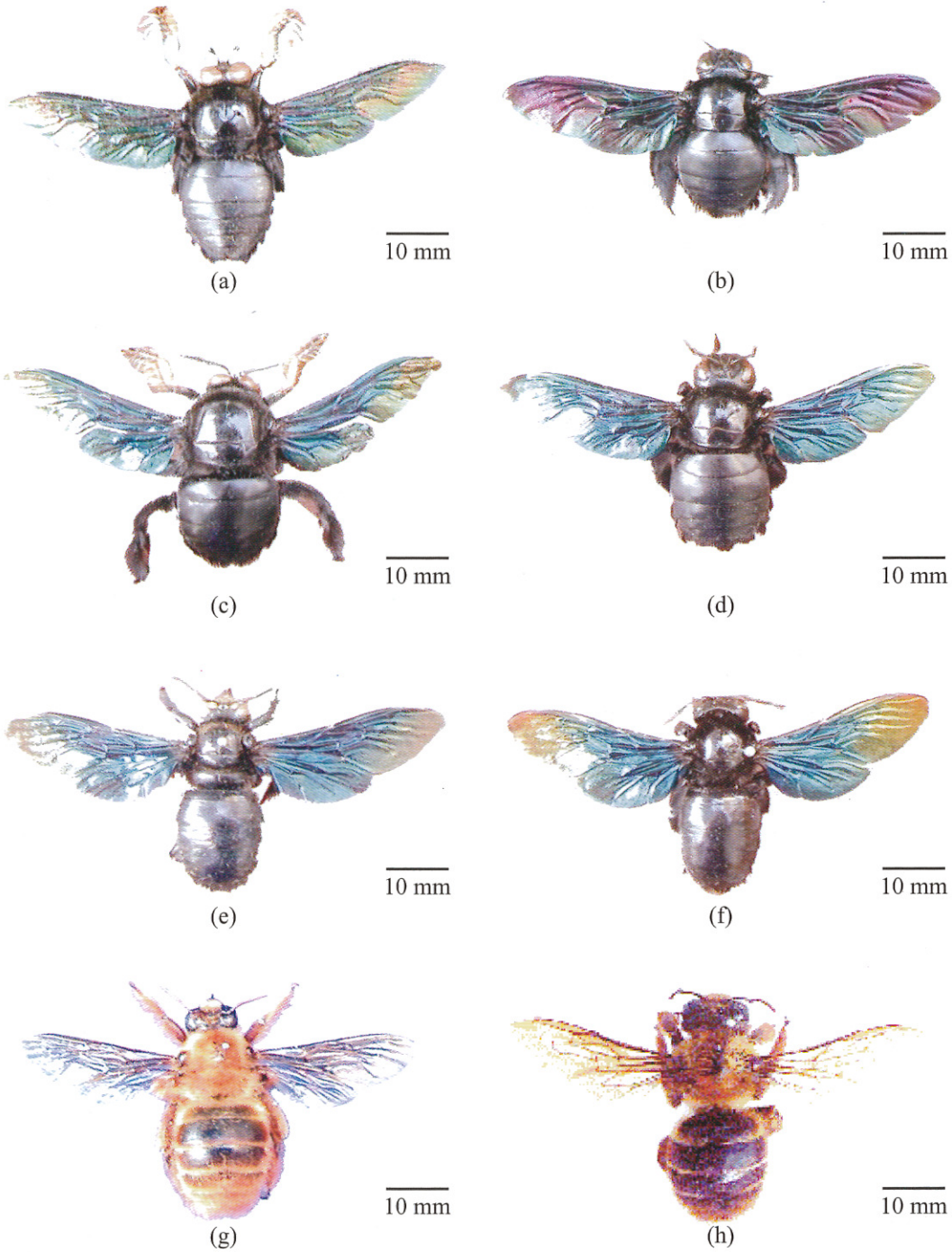


Figure 3.1 Species of large carpenter bees
a) *X. latipes* : male
b) *X. latipes* : female
c) *X. tenuiscapa* : male
d) *X. tenuiscapa* : female
e) *X. nasalis* : male
f) *X. nasalis* : female
g) *X. tranquebarica* : male
h) *X. tranquebarica* : female

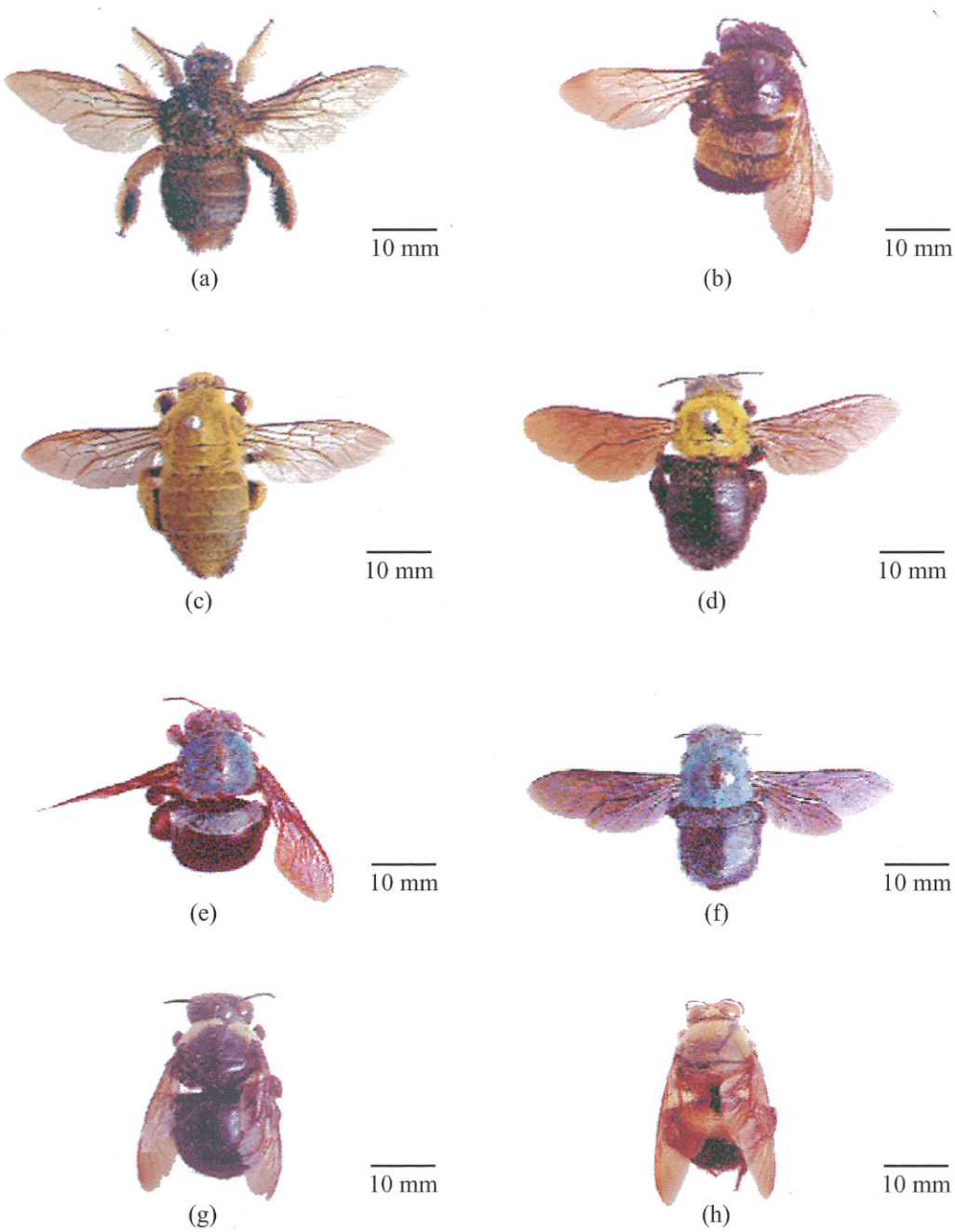


Figure 3.2 Species of large carpenter bees
a) *X. rufescens* : female
b) *X. verticalis* : female
c) *X. aestuans* : male
d) *X. aestuans* : female
e) *X. caerulea* : female
f) *X. abbotti* : female
g) *X. collaris* : female
h) *X. basalis* : female

Table 1 Measurements of bamboo substrate established by *X. nasalis* carpenter bees

Nest No.	Interode length	Opening Location Between Nodes		Size of Opening		Internal diameter	Number of Bees		Living Organism
		Lower part	Upper part	Height	Width		Male	Female	Found in Nest
1	33.0	8.5	24.5	1.2	1.3	1.4	2	5	
2	31.5	10.4	21.1	1.0	1.2	1.4	1	3	
3	30.5	7.3	23.2	1.0	1.4	1.5	0	4	
4	47.0	20.0	27.0	1.2	1.4	1.6	3	6	Blister Beetle
5	25.5	11.0	14.5	1.0	1.2	1.5	0	3	
6	33.0	7.5	25.5	1.5	1.7	1.7	0	4	
7	27.5	10.5	17.0	1.1	1.3	1.6	1	3	
8	34.0	7.0	27.0	1.1	1.4	1.6	0	0	Ant
9	40.0	13.0	27.0	1.1	1.2	1.4	1	6	
10	42.0	12.2	29.8	1.1	1.3	1.5	2	7	
11	34.2	8.2	26.0	1.3	1.4	1.6	3	5	
12	32.0	10.5	21.5	1.5	1.6	1.8	0	0	Snake
13	30.2	7.4	22.8	1.2	1.4	1.5	1	6	
14	42.3	16.0	26.3	1.1	1.3	1.5	2	13	
15	26.5	12.7	13.8	1.0	1.2	1.4	0	4	
16	31.0	8.5	22.5	1.3	1.4	1.7	1	4	Parasitic wasp
17	19.5	10.7	18.8	1.1	1.3	1.6	2	5	
18	33.0	16.3	16.7	1.2	1.4	1.6	1	6	
19	29.0	9.2	19.8	1.3	1.4	1.7	2	8	
20	31.0	11.5	19.5	1.2	1.5	1.7	1	7	
Mean	**32.63**	**10.92**	**22.21**	**1.18**	**1.35**	**1.56**	**1.15**	**4.95**	

Preliminary biological study of *X. nasalis* uncovered that there existed three categories of social behavior for the carpenter bees, beginning with a solitary life marked by self-foraging followed by a period of mating, laying eggs and preparing food for the young through progressive mass provisioning as well as caring for the offspring. This period can be referred to as the subsocial period. The third period involved young adult bees co-habiting with their mother up to a period of time prior to their eventual permanent departure, whereupon the cycle would be repeated starting with the solitary life. Each of the brood cell contained a mix of nectar with pollen grains called of 10-15 mm in size, spherical in shape. Eggs were deposited on top of the accumulated food residue known as the pollen load. The beeís saliva combined with scraps from chipped surface of the bambooís internal layer formed a partition with a thickness of 1-2 mm, separated from each cell. The process was repeated with a maximum

of 15 cells in each nest. The size of the full-grown larva was measured at 25-35 mm. Upon reaching its full-grown size, the larva would consume all the rations that were gathered by its mother and molted themselves in preparation for entering into the pupal stage. At this stage the pupa would exhibit a white body to a black body and incurred a development period of 13-14 days.

Furthermore, an important discovery should be noted in the process of the pupal development cycle to enter into the adult stage. The observation revealed an intermediate stage of 20-22 days in which the subimmago-like insect consisted of a black body, undeveloped wings (wing pad), pointed craw-like legs, and relied upon food rations provided by mature bees. Following this intermediate stage, the subimmago would again molt into a young adult, consisting of white opaque wings that would gradually assume the normal color of black with a splash of transparent green, blue and purple towards the end. Adult bees cohabited with their mother within the nests until their departure, a behavior-exhibiting stage known as quasisocial. (figure 4)

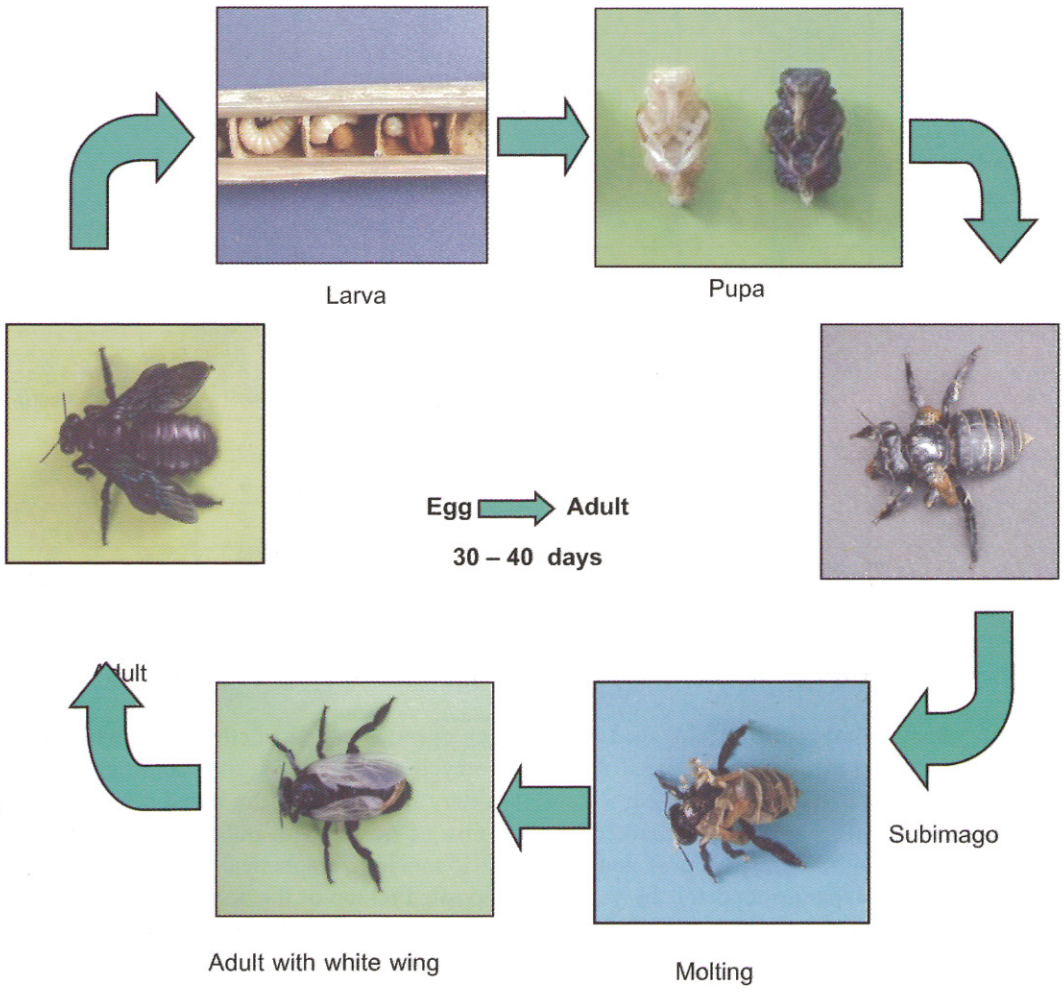


Figure 4 Biology of *Xylocopa nasalis*

Other living organisms were also discovered to co-exist within the nested domain of carpenter bees and included 4 species, such as the Cissites maxillosa Fabricious (Family Meloidae). The bristle beetle dwelt deep within the innermost part of the carpenter beesínest, from which it survived by consuming one larva and then entering into the pupa stage before eventually and leaving the nest once it had emerged as an adult offspring. The endoparasitic wasp Ophelimus sp. (Family Eulophidae) was found to have devoured the inside of the bee larva, consuming all mass particles while leaving only the outer skin intact. In addition, the common bridle snake : Dryocalamus davisonii (Family Colubridae) and Camponotus sp. (Family Formicidae) were also discovered to have resided within one of the bamboo stems. (figure 5)

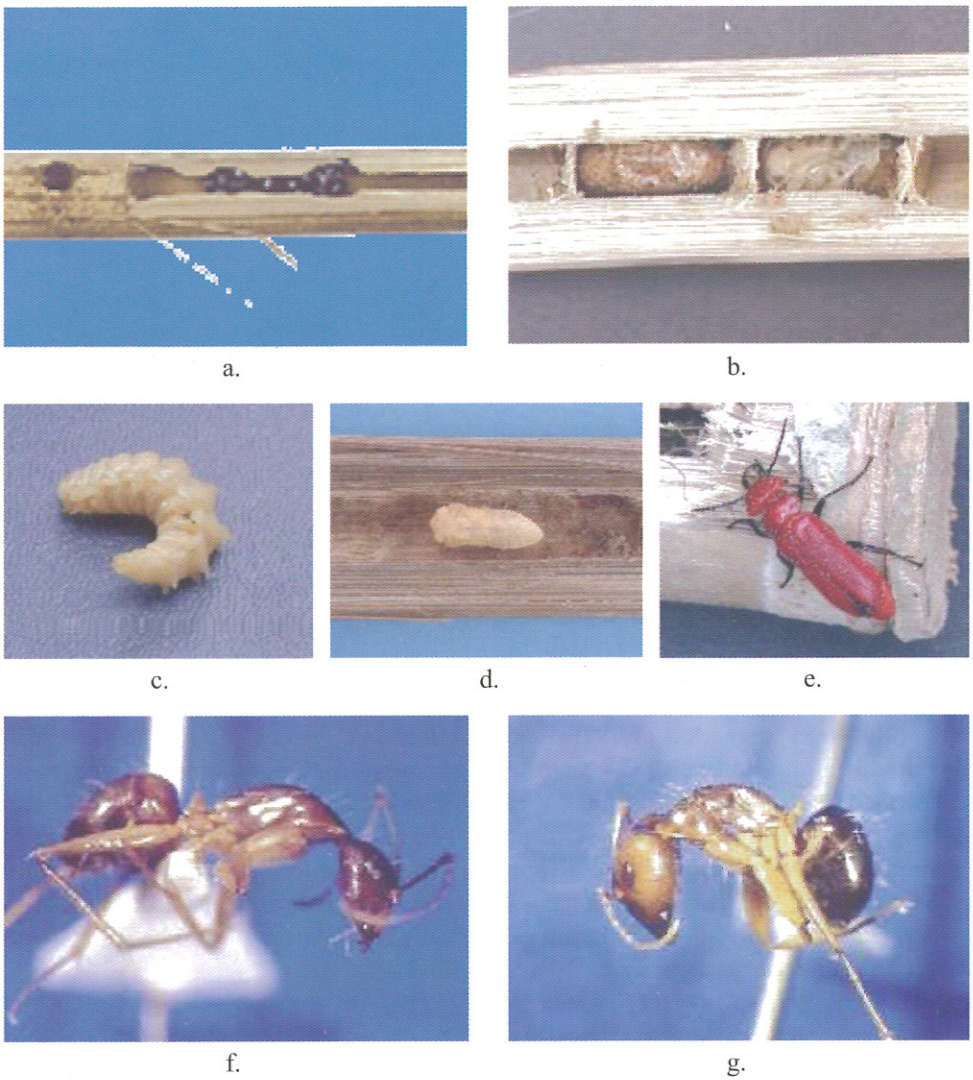
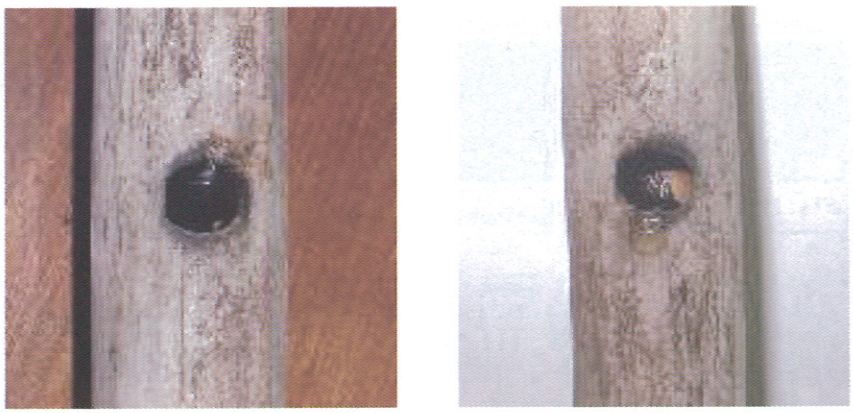


Figure 5 Living organism found in nest
a) Common bridle snake : Dryocalamus davisonii
b) Bee larva are parasitized by parasitic wasp : *Ophelimus* sp.
c-d-e) Larva, pupa and adult of *Cissites maxillosa* F.
f-g) Worker and soldier of *Camponotus* sp.

The behavioral component of the carpenter bee (*X. nasalis*) in the protection of its nests included the capacity to curl-up the upper part of the gaster, which would be directed outward in an effort to safeguard the opening, all performed whilst the bee was situated within the stem. Upon being offensively disturbed by its enemy, the carpenter bee would protrude the end of the gaster and squirt 5-6 drops of highly pungent, yellowish liquid in the distance of 17-30 cm. (figure 6). Furthermore, once the continuous disturbance proved to prolong beyond the beeís capacity to protect itself, it would leave the nest, leaving its offspring behind.



(a) (b)

Figure 6 Behavioral components of the carpenter bee in protecting the entrance to its nest:
a) Curling its gaster to seal the opening
b) Squirting pungent liquid to thwart enemy intruders

DISCUSSION

Observations obtained through studies conducted between the period of 1999-2005 combined with information gathered from institutions, such as Department of Agriculture, Ministry of Agriculture and Cooperative. Department of Entomology, Faculty of Agriculture, Kasetsart University, Museum of Deprtment of Pest Management, Faculty of Natural Resource, University of Songklanakarin and the Department of Entomology, Faculty of Agriculture, Changmai University, provided further revelation to the identification key stated by Savitree (1992) whereupon 11 species were uncovered as oppose to the 9 species formerly discovered. Using information from The Fauna of British India Vol I: Wasps and Bees (Bingham, 1897) and A Classification of the Large Carpenter Bees (Xylocopini) (Hurd and Moure, 1963) a conclusion was reached regarding the synonym of the *X. nasalis* and the *X. dissimilis*. In addition, this study provided further insights on the identification of other species, but no records were yet made due to lack of available information to support the findings. If more information became available in the future, then this study can be further pursued, in which potentially newer species could be reported in Thailand.

In summary, the social life of the *X. nasalis* consisted of three categories, beginning with a solitary life, mating, laying eggs, and preparing food for the offspring, resembling the subsocial insect. (Malaipan, 1992) The quasisocial life, an extension of the period that was not formerly mentioned in the Savitreeí study,

represented the third period in which young adult bees co-habited with their mothers up to a period of time prior to their eventual permanent departure. In addition, more stage was discovered and, due to insufficient information available, was assigned a descriptive term known as the "active wing pad stage," which succeeded the white pupal stage prior to the development into the adult offspring.

Furthermore, findings also uncovered additional species such as *Ophelimus* sp. that differed from previous studies Leucopsis sp.regarding Hurd and Moure (1963) . Behavior exhibited in connection with the carpenter beeís capacity to protect its nest proved to resemble behavioral characteristics described for the *X. fenestrata* found in India by Kapil and Dhaliwal (1968)

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