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On the Biology of *Xylopsocus bicuspis* LESNE, 1901

(Coleoptera: Bostrichidae)

Lan-Yu LIU, Klaus SCHÖNITZER & Jeng-Tze YANG

Abstract

The adult galleries, larvae, pupae and pre-emergence adults of *Xylopsocus bicuspis* LESNE, 1901, and the adult gallery of *Bostrychopsis parallela* (LESNE, 1895) attacking branches of *Cinnamomum* sp. collected in eastern Taiwan are described. The biology and immature stages of the species are compared with those of other bostrichids.

Introduction

The family Bostrichidae has a world-wide distribution but is mainly found in tropical and arid areas. There are seven subfamilies, 90 genera and more than 550 known species which vary from small to large in size (LESNE 1938; IVIE 2002). The seven subfamilies are Bostrichinae, Dinoderinae, Psoinae, Lyctinae, Endecatominae, Dysidinae and Euderinae (IVIE 2002). Bostrichinae are divided into 5 tribes, Dinapatini, Apatini, Bostrichini, Xyloperthini and Sinoxylini. The Psoinae and Lyctinae both are divided into two tribes, Polycaonini and Psoini belong to the former and Lyctini and Trogoxylini belong to the latter. The Dinoderinae, Endecatominae, Dysidinae, and Euderiinae all include a single tribe only (IVIE 2002).

Bostrichidae mainly feed on and breed in bamboo, timber, rattan, stored grain, and the products made from bamboo and timber. Their recorded plant hosts extend to at least 40 families, and probably almost any family with woody species can be attacked. The most commonly attacked families include Bambusaceae, Mimosaceae, Lauraceae, Caesalpiniaceae, Papilionaceae, Fagaceae, Moraceae and some others, even Pinaceae and Cupressaceae are included (BEESON & BAHATIA 1937; CHU & ZHANG, 1997). Hence, Bostrichidae are important pests of wood, and wooden and bamboo cultural properties and structures (MIURA et. al., 2001).

Most Bostrichids have a hypognathous head which is not visible from above, but the head is prognathous in Psoinae and Lyctinae (FISHER 1950, GERBERG 1975, IVIE 2002). The pronotum is large and cowled, or flat; in cowled species the anterior dorsal surface is rough and rasp-like, and may have curved horns or hooks at the anterior angles (FISHER 1950, IVIE 2002). Elytra are highly variable, usually coarsely punctate, often with a distinct apical declivity variously modified with spines (FISHER 1950).

Xyloperthini is a rather large tribe of Bostrichidae, containing 32 genera, which are found in all parts of the world (FISHER 1950). *Xylopsocus* is a genus of Xyloperthini mainly distributed over the Palearctic, Oriental and Australian regions. *Xylopsocus bicuspis* LESNE, 1901 has only been recorded from Taiwan and Japan (LESNE 1938, LIU et al. 2006).

We describe the gallery, larva, pupa and pre-emergence adult of *Xylopsocus bicuspis* and the gallery of *Boschychopsis parallela* (LESNE, 1895) in this paper, based on observations made by the first author. *B. parallela* is a member of Bostrichini and about 2 times bigger than *X. bicuspis*. This is the first paper to report the biology of *X. bicuspis* and illustrate the galleries of *X. bicuspis* and *B. parallela*.

Methods and Materials

In the middle of June 2007, we were given a pile of branches and twigs of *Cinnamomum* sp. from east Taiwan (Taitung, Li Jia forest trail) at an elevation of about 500m. We collected a great number of *Xylopsocus bicuspis* from the pile of branches during the following two months (July, August).

Figs 1-3: Fig. 1. Galleries of *Xylopsocus bicuspis* with a larva at the right bottom (in circle) (debarked branch). **Fig. 2.** The branch attacked by *Xylopsocus bicuspis*, arrow points out a pupa (debarked branch). **Fig. 3.** Split branches heavily attacked by *Xylopsocus bicuspis*, arrows point out three adults.

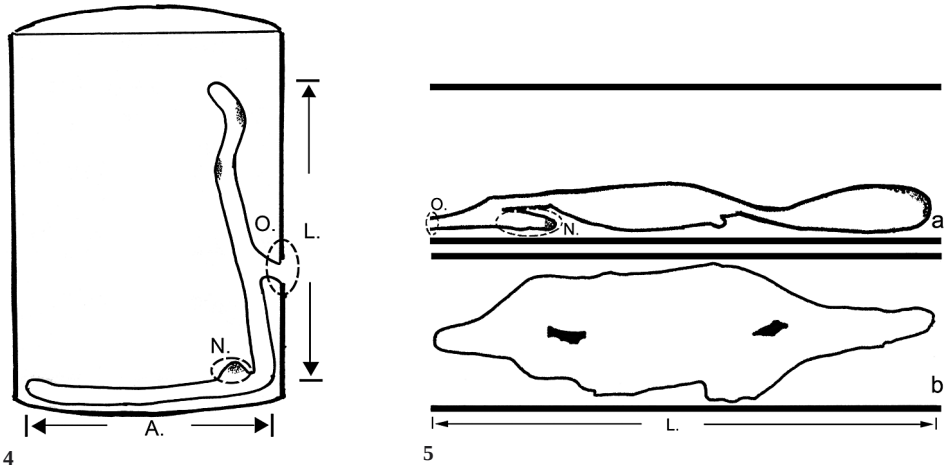
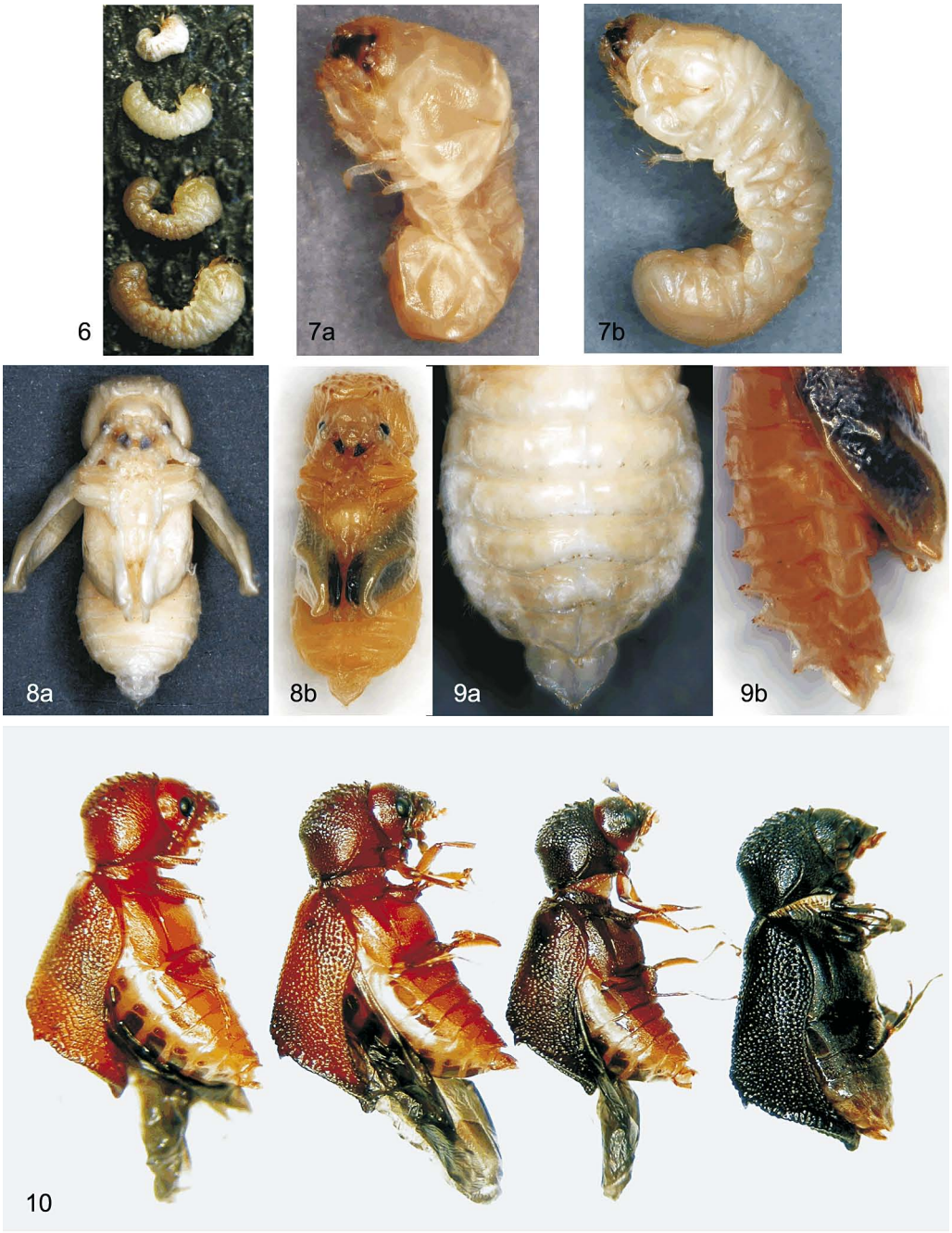


Fig. 4-5: Fig. 4. Schematic diagram of the adult gallery of *Xylopsocus bicuspis*. **Fig. 5.** Schematic diagram of the adult gallery of *Bostrychopsis parallela*

a. cross-sectional view along the longitudinal axis of the branch.

b. surface view of the sapwood of the branch. Black ‘islets' are table-like elevations of solid wood, not excavated by the beetles.

A annular gallery, **L** longitudinal gallery, **N** nuptial chamber, **O** opening (Terminology according to LESNE 1924).



Figs 6-10: Fig. 6. The four instar larvae (2nd - 5th instar) of *Xylopsocus bicuspis*. **Fig. 7.** The larvae of *Xylopsocus bicuspis*. **a.** the lateral view of 2nd instar larva. **b.** the lateral view of mature larva. **Fig. 8.** The pupa of *Xylopsocus bicuspis*. **a.** the earlier pupa **b.** the mature pupa. **Fig. 9.** Abdomen of pupae *Xylopsocus bicuspis*. **a.** dorsal view of earlier pupa. **b.** lateral view of mature pupa. **Fig. 10.** Different stages of pre-emergence adults from left and adult *Xylopsocus bicuspis* (right).

The behavior of adult beetles was observed as far as possible outside the branches. In several cases it was observed that the beetles started boring new galleries, i.e. infecting further in twigs that had been attacked before and in previously unattacked twigs. Galleries with beetles and larvae were investigated by cutting open twigs or removing the bark and frass.

The larvae, pupae and pre-emergence adults were preserved in 70% Alcohol and observed using a light microscope. Photographs of various stages of *X. bicuspis* were taken using the microscopic camera (JENOPTIK, ProgRes C3) under the light microscope and combined using Auto-Montage ® 4.03.0071.

Results

Gallery

Xylopsocus bicuspis prefer to start the gallery from the place where the branch or shoot originated, near a leaf node, or under or between the pieces of branch which we previously had split open. After digging into the sapwood, *X. bicuspis* adults extend the gallery around the branch ('annular gallery'), but the larvae developed their galleries along the long axis of the logs (Figs 1, 2).

The galleries of *X. bicuspis* larvae are packed with fine wood dust and excreta, and the larvae are found buried in the dust. There is no frass in adult *X. bicuspis* annular galleries which are totally empty. The larvae bore rather straight galleries along the long axis of the logs from where the eggs were laid. There are usually more than tens of larvae developed in one branch, some of them developed their galleries toward one end of the branch and other ones developed their galleries toward the other end of the branches.

The diameter of the galleries increases as the larvae develop. The more mature larvae are found closer to the surface of the branch, and the mature larvae make cells at the terminal ends of the larval galleries just underneath the surface for pupation.

After eclosion, the pre-emergence adult starts feeding but stays in the pupal chamber or moves backward into the gallery while the cuticle hardens and darkens. *X. bicuspis* spends almost all its life in the gallery until the cuticle has hardened, e.g. the time of courtship, and then continues feeding on wood in the gallery after mating. This explains why the bostrichids have rarely been noticed in the field until the adult made an exit hole to emerge, and this lets the frass drop out. We did not observe mating of *X. bicuspis*, because they always immediately ran into the shadow, under the branches or back to the galleries when illuminated.

The galleries that we observed and depicted of *X. bicuspis* were sometimes also occupied by *Xylothrips flavipes* (ILLIGER, 1801) when we found them. *X. flavipes* is also a member of Xyloperthini but bigger than *Xylopsocus bicuspis*. The size of *X. bicuspis* is 3.5 - 5.0 mm in length and 1.4 - 1.8 mm in width. The size of *X. flavipes* is 6.5 - 8.0 mm in length and 2.5 - 3.0 mm in width. There was only one type of gallery found whether made by *X. flavipes* or by *X. bicuspis* in the branches observed. Whether *X. flavipes* inhabit galleries from *X. bicuspis* or vice versa could not clearly be decided by our observations. At any case the two species inhabit the same kind of gallery. In our observations, the population of *X. flavipes* was far less than that of *X. bicuspis* in the pile of branches of Cinnamon trees. But *X. flavipes* showed up very often in the gallery where we found few adult *X. bicuspis*. Usually only one or two *X. flavipes* and more than three *X. bicuspis* adults were in one gallery together.

Furthermore we observed galleries of *Bostrychopsis parallela* (Fig.5) in the pile of branches and twigs of *Cinnamomum* sp.. *B. parallela* is a rather big species of Bostrichini, the male is 10 - 12 mm in length and 3.5 - 4.0 mm in width, and female is 7.5 - 8.5 mm in length and 2.0 - 2.5 mm in width. We collected less than 10 specimens of *B. parallela* from the pile of branches. The gallery of B. *parallela* is usually very broad extending through almost the whole depth of the sapwood of the branch, and usually occupied by a pair (one male and one female). Other bostrichids were never found in the same gallery as *B. parallela*. One gallery was found with 2 females and one male, and another gallery with only one male. The galleries of *B. parallela* adults are totally empty of frass just as the *Xylopsocus bicuspis* adult galleries. We did not find any larvae of *B. parallela*.

There is usually an enlargement of the gallery near the angle of the gallery (Fig. 4, N) or the opening of the gallery (Fig. 5a, N). Adults were often found in this enlargement when the logs were split open. If a pair of *B. parallela* was hidden in the nuptial chamber together, the male was found at the end of the chamber with its back towards the end of the chamber, and the female in front of the male with its head towards the opening of the chamber.

We found the galleries of *B. parallela* only in small twigs with a diameter of up to 3cm. We can not really tell if *B. parallela* never infects larger branches and makes galleries similarly composed of longitudinal and annular parts in the larger branches as described above for *Xylopsocus bicuspis*. It needs further study.

Larva

We observed four larval instars of *X. bicuspis* (Fig. 6). All of them are roughly C-shaped in outline with the small head deeply retracted into the greatly developed prothorax. The legs are well developed from the first instar what we found (Fig. 7a). From the third instar what we found, the transverse groove on the lateral side of the thorax becomes very apparent (Figs 6, 7b).

Pupa

The young pupa is creamy-white in colour. The pupal head has developed antennae and eyes (Fig. 8). The pupal legs are free from the body and the hind legs are usually covered by the elytra. The outline of the pupal abdomen is essentially the same as that of the adult. The darkening and hardening of the cuticle starts with the eyes and the apex of the mandibles.

The middle part of the behind margin of each tergum of abdomen hardens to form a transverse ridge which gradually rises up toward to the mid-line of the tergum (Fig. 9).

Pre-emergence adult

The pre-emergence adult is very similar to the emerged adult except for the lighter and softer cuticle. The color of the elytra and body surface becomes darker as the cuticle hardens gradually. The abdomen of the pre-emergence adult is obviously softer and more swollen than in adult, so the elytra do not cover the abdomen.

Discussion

Gallery System

The gallery is the main sphere of activity of Bostrichids, because they pass the greater part of their life in galleries in the wood (RAI & CHATTERJEE 1963). Similarly, SOLERVICENS and VIVAR (1976) observed the life cycle of *Polycaon chilensis* (ERICHSON, 1834) and also found the beetles spending most of their life in the galleries.

Many species begin as a pair to bore a gallery which serves as a living place for the parents, and they work together in the gallery. The essential part of the adult gallery usually develops into an arc of a circle, often an almost complete circle, in the superficial part of the wood, below the bark (LESNE 1924). LESNE (1924) named the circular gallery the 'annular gallery' (Fig. 4A.). The longitudinal galleries (Fig. 4L.) arising from the annular gallery sometimes complete the gallery system (LESNE 1924).

In 2000, tens of thousands of *Sinoxylon japonicum* LESNE, 1895 were found attacking the two to three years old young flamegold trees (*Koelreuteria integrifolia*) in Loyang, China (ZHAO & HO 2000). *S. japonicum* bored a gallery around the circumference of the branch but never completed a whole circle. They will leave to find a new place near the base of a leafstalk to start a new gallery (ZHAO & HO 2000). *X. bicuspis* adults also bore the galleries around the branch as *S. japonicum*, never completing a whole circle.The larvae of *Sinoxylon crassum* LESNE, 1897 also make cylindrical larval galleries along the long axis of the sapwood of logs (RAI & CHATTERJEE 1963). *Polycaon chilensis* develops its galleries along the longitudinal axis of branches, and never digs deeper than 3cm from the surface of the branch (SOLERVICENS & VIVAR 1976). This means that *P. chilensis* develop their gallery in the sapwood too. This is probably because only the sapwood contains sufficient nutrients for the adults and for larval development.

LESNE (1924) mentioned that the opening of the gallery system is generally in the middle portion of the annular gallery with a very short gallery onto the bark surface. According to our observations, however, the openings (Fig. 4O) of the galleries of *Xylopsocus bicuspis* are usually in the longitudinal gallery. After the adult bored through the bark, it bored a short gallery vertical to the surface, and then turned downward or upward to develop part of the longitudinal gallery. The first part of the longitudinal gallery sloped toward the bark, but then the adult turned to develop the annular gallery (Fig. 4).

There is often an enlargement (Fig. 4N) at the junction point between the longitudinal gallery and annular gallery. The enlargement has been called the nuptial chamber (LESNE 1924). In the case of *Bostrychopsis parallela*, there is only one simple broad longitudinal gallery without an annular gallery (Fig. 5), and the enlargement (Fig. 5N) is near the opening (Fig. 5O) in the longitudinal gallery.

LESNE (1924) suggested the nuptial chamber possibly ought to be called 'eversing or turning chamber' because beetles can turn round or reverse direction here in the course of their feeding and burrowing activities. We found *Xylopsocus bicuspis*, *Xylothrips flavipes* and *B. parallela* usually hid themselves in the enlargement when we split the gallery open. So in addition to mating and turning, the enlargement offered a temporary refuge to the beetles.

LESNE (1924) noted that the mating of Bostrichids can occur on the surface of the branch, or at the external opening of the gallery or in the nuptial chamber. SOLERVICENS and VIVAR (1976) doubted whether *Polycoan chilensis* mated in the galleries. ZHAO and HO (2000) found *Sinoxylon japonicum* mated on the surface of branches, but most references to the biology of Bostrichids do not mention where they mate. Hence, we suppose the Bostrichids mate mainly in the galleries where it is difficult to observe, but may mate on the bark surface in some circumstances.

A certain number of species (various Lyctinae, *Lichenophanes*, etc.) do not make galleries for oviposition. The female lays her eggs on the surface of branches or tree trunks, or in fissures in the wood, to the bottom of which she inserts her long and very mobile ovipositor (LESNE 1924). Many studies (SNYDER 1916, ALSTON 1923, PARKIN 1934, ROSEL 1969) noted that lyctine females lay their eggs in the big pores of the xylem vessels in sapwood of hardwood and bamboo.

Other Bostrichids sometimes laid the eggs on the walls of the annular gallery, sometimes on the wall of the longitudinal galleries, or sometimes inserted in the cavities of the ligneous cells cut across by the gallery. In most cases, the female having completed oviposition goes to die at the gallery entrance in such a position that her elytral declivity exactly obstructs the entrance. This prevents the entry of spiders, nesting Hymenoptera, and predatory Coleoptera which might develop at the expense of the bostrichid brood (LESNE 1924). NANSEN and MEIKLE (2002) found *Prostephanus truncatus* males generally spend most of the time in the entrance of the tunnel, independent of the presence of a female in the tunnel, possibly for territorial reasons.

Not many references to the life history of Bostrichidae illustrated the galleries. BEESON and BHATIA (1937) illustrated the galleries of *Dinoderus* in bamboo, and a few references provided photos of the galleries of *Lyctus* (FISHER 1929, PARKIN 1934, WRIGHT 1960) and *Sinoxylon* (FREDIANI 1961).

The galleries of *Xylopsocus bicuspis* larvae are packed with fine wood dust and excreta, in the same way as the galleries of *Sinoxylon crassum* larvae (RAI & CHATTERJEE 1963), *Polycaon chilensis* larvae (SOLERVICENS and VIVAR 1976) and *Sinoxylon perforans* (SCHRANK,1789) larvae (FREDIANI 1961:35). The larvae are found buried in the dust. No paper above mentioned whether the adults' galleries are empty or not. But we found the adults' galleries of *Xylopsocus bicuspis* and *Bostrychopsis parallela* are totally empty. Except for adult bostrichids can move the frass outside the galleries, it probably shows the bostrichids adult and larva have different requirements about food and habitat, and may be related to the ecto-symbiotic bacteria and fungi which may grow in the frass in larvae galleries. This ought to be investigated further.

From the observation of the galleries of Bostrichids, we found the same branches could be attacked by successive generations of *Xylopsocus bicuspis*. In the end, this made the whole branch totally into fine powder. The combined work of the many larvae of successive broods and generations results in the complete conversion of the sapwood into fine powder, that is, 'powder-posted' wood which becomes honey-combed with irregularly bored tunnels. Only a thin layer of bark which is easily penetrated, is left covering the branch (RAI & CHATTERJEE 1963, ZHAO & HO 2000). It means that Bostrichids probably do not have to disperse in each generation to find new host trees for the new generation, at least before the original host is totally exhausted as a source of food. Since high mortality is likely to occur during dispersal, the bostrichid population can potentially increase in size more rapidly.

Larva

In the species that lay their eggs on the surface of branches, the first instar larva has a staphyliniform facies - the axis of the body is straight, the legs are relatively long and furnished with a well-developed claw and the integument bears a small number of very long erect hairs (LESNE 1924). This larva can move around very agilely. In other cases, in which the egg has been inserted into a cavity in the gallery wall or a xylem vessel, there is no wandering stage. The first instar larva has no long hairs, and has only rudimentary legs and molts after several days into a second instar which has a curved body (LESNE 1924). *Xylopscous bicuspis* female lays eggs in the gallery, but we did not observe where the female lays eggs, on the wall of longitudinal gallery or annular gallery.

The larvae we found from the galleries actually all have well-developed legs already, which suggests we did not find the first instar larva and *X. bicuspis* has five larval instars. *X. bicuspis* larva is the typical Bostrichid larva and typical Xyloperthini larva. The chief characters of the mature larvae of Bostrichidae are: head deeply retracted into the thorax, antennae with three segments, mandibles usually gouge-shaped distally, legs usually well developed, body curved, enlarged at thorax, and tenth abdominal segment in front of anus with a pair of adjacent lobes separated by a longitudinal groove (GARDNER 1933). The mature larvae of Xyloperthini have the anterior legs distinctly stouter than the others. Attenuate claws are present on all legs (GARDNER 1933). From the fourth instar of *Xylopsocus bicuspis*, a transverse groove on the lateral side of the prothorax becomes very apparent (see also GARDNER 1933 pl. iv. fig.43, larva of *Amphicerus anobioides* WATERHOUSE, 1888).

In our observations, the legs and the lateral margins of the thorax and abdomen are fringed with long dark yellow hairs. These hairs and the attenuate claws should be helpful to move in the frass. It will be worthwhile to study these hairs and the attenuate claws further by SEM.

Pupa

This paper is the first one mentioning the pre-emergence adult stage of Bostrichidae. Further studies about this stage of Bostrichidae are needed.

In the prepupal stage, the mature larva contracts, and the body becomes straight. After the last molt it becomes a pupa. LESNE (1924) thought there are no special preparations before the transformation, but IWATA and NISHIMOTO (1985) still named the mature larva in a straight body shape 'prepupa'. But IWATA and NISHIMOTO (1985) did not clearly distinguish between the mature larva and 'prepupa'. They supposed the mature larva could not transform into a prepupa when they moved the larva from the artificial diet or wood into an open dish.

The pupal chambers of bostrichids are not normally coated with ement and no cocoon is formed. The only exceptions are certain species of *Dinoderus* living in dried sweet potatoes where the larva makes a cocoon with the help of its faeces at the time of metamorphosis. The cocoon becomes cast and hardens as it dries (LESNE 1924).

In *Apate*, the dorsal side of the pupa bears a system of ridges or projections, usually spinulose, but sometimes simply setigerous, which enable the pupa to move rapidly within the gallery which it inhabits (LESNE 1924). In *Xylopsocus bicuspis*, the middle part of the posterior margin of every tergum of the abdominal segments hardens to form the transverse ridge (Fig. 8). The ridge gradually rises up towards the mid-line of the tergum. These ridges probably enable the pupa to move in its cell like the pupa of *Apate*.

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Zusammenfassung

Die Fraßgänge der adulten Käfer im Holz von *Cinnamomum* Sträuchern (Lauraceae) sowie die Larven, Puppen und Adulti vor dem Schlüpfen von *Xylopsocus bicuspis* LESNE, 1901 werden beschrieben und abgebildet. Außerdem werden die Fraßgänge von *Bostrychopsis parallela* (LESNE, 1895) beschrieben. Das untersuchte Material wurde in Ästen gefunden, die im Osten von Taiwan gesammelt wurden. Die Biologie und die Juvenilstadien werden mit denen von anderen Arten verglichen.

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Authors addresses:

Lan-Yu LIU & Jeng-Tze YANG
Department of Entomology
Chung Hsing University
Taichung, 250 Kuo Kuang Road
Taichung 40227
TAIWAN

Klaus SCHÖNITZER
Zoologische Staatssammlung München
Münchhausenstraße 21
81247 München
GERMANY

Corresponding author: Jeng-Tze YANG
email: jtyang@drogon.nchu.edu.tw