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Unravel the Century-old Mystery of Trictenotomidae: Natural History and Rearing Technique for *Trictenotoma formosana* Kriesche, 1919 (Coleoptera: Trictenotomidae)

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Abstract: This paper reports the detailed biological information of Taiwanese *Trictenotoma formosana* Kriesche, 1919 involving its natural history, life cycle, rearing technique, and observations under artificial conditions, which is the first study of Trictenotomidae. Both larval diet and adult habits are also addressed. Further life cycle observations including photographs of larval group, feeding situation of adults and larvae, the tunnel built by the larva, pupal cell and newly eclosed adult are also provided.

Key words: Trictenotomidae, *Trictenotoma*, natural history, rearing technique, larva

Introduction

The family Trictenotomidae Blanchard, 1845, a small group in Tenebrionoidea consisting of only two genera and fifteen species (Telnov, 1999; Drumont, 2006; Drumont, 2016), distributes in the Oriental and southeastern Palearctic regions. Though trictenotomids are large and conspicuous beetles and even very common in insect specimen markets, its natural history is less known. In Trictenotomidae, all species are forest inhabitants and adults are known to be active nocturnally and are collected easily by light attraction (Pollock & Telnov, 2010). Gahan (1908) provided a description of the mature larva of *Trictenotoma childreni* Gray which only mentioned that it was found with the debris of pupae and imagines but without detail about microhabitat. Up to now, Gahan (1908) is the only published information about the larva and larval habitat of Trictenotomidae.

The habitat of trictenotomid larvae has been a fascinating issue, "where are the trictenotomid larvae?", for many coleopterists from early 20th century, and yet, it is still a puzzle. Owing to the phylogenetic position of Trictenotomidae and other families in Tenebrionoidea is still unclear, the background knowledge of larval biological information might be contributed to our understanding of its relationships to other members. Indeed, Lin & Hu (2018) had observed and recorded the oviposition behavior of *Trictenotoma formosana* Kriesche, 1919 under artificial conditions. More information of life stage would be descripted herein.

In the original paper describing *T. formosana* (Kriesche, 1919) based on specimens from "Formosa, Taihorin" (= Dalin Township, Chiayi County, Taiwan), this species was regarded as a subspecies of *T. davidi* Deyrolle. After few years, Kriesche, (1921) elevated this subspecies to species level. Thus, the valid scientific name is *Trictenotoma formosana* Kriesche, 1919. This species was only known from the original description and there have not been any additional collecting records since then; it would appear *T. formosana* is endemic to Taiwan.

During 2017 to 2018, the first author observed adults of *T. formosana* in their natural habitat in Sanyi Township, Miaoli County along with Tongxiao Township, Miaoli County, and tried to figure out the rearing technique for this species. In the present study, we describe the natural history of *T. formosana* and provide the results of rearing information under artificial conditions.

Materials and methods

All adults of *Trictenotoma formosana* were collected by first author from Sanyi Township, Miaoli County and Tongxiao Township, Miaoli County. The detailed information of the habitat was mentioned in "**Natural History**". We followed the steps mentioned in Lin & Hu (2018) and let the females oviposit under the bark successfully. After the larvae hatched, we placed about 60 larvae in a plastic cup (diameter: 7cm; height: 4.5cm), with half cup of fermented decayed wood flakes. However, we discovered that the larvae were eating each other, so we reared each larva in a cup and feed them the larvae of *Zophobas morio* (Tenebrionidae) as food source. Takada & Takahashi (2013) found that some carnivorous beetle larvae will eat cat food under artificial conditions.

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Therefore, we also added wet cat food to the cups; this was changed to fish food, which was soaked in water for 5 minutes and then placed on the surface of rearing medium every two days. We changed the fermented decayed wood flakes of the cups every 10 days to prevent the emergence of mites. After the length of larvae reached 4 cm, we moved the larvae to the square plastic boxes (length: 14 cm; width: 10 cm; height: 7.5 cm), which were filled with fermented decayed wood flakes. After the larvae reached 8 cm, we changed it to a larger box (length: 38 cm; width: 24 cm; height: 15 cm) with various materials to test the potential pupation environment. The materials in the separate boxes were as follows: pure flake soil; pure flake soil with hard decayed wood (*Liquidambar formosana*); the first half of the box full of flake soil, the second half of the box full of dirt; the first half of the box full of flake soil, the second half of the box full of dirt with hard decayed wood (*Liquidambar formosana*); pure decayed wood flakes (*Quercus glauca*). If we observed that a larva had built a pupal cell, the pre-pupa or pupa would be moved out and placed in an artificial pupal cell using flower arrangement sponge for easier observation. The immature stages were kept at a moderate humidity, with average temperatures 20–22℃ (the lowest to the highest: 7–35℃).

Ecological habits of *T. formosana* were observed from 2016 to 2018 in the same locality where adults were collected. The description of the natural history of the larval section was based on Mr. Tzu-Yi Yu, a local observer.

All photos were taken by using an Olympus Stylus TG-4 Tough digital camera except the photos from Mr. Tzu-Yi Yu and Mr. Ming-Huei Liu, which of them were montaged by Adobe Photoshop CS5 and Photo Cap 6.0 if necessary.

Results

Life cycle and observations in the artificial condition

The life cycle of *T. formosana* under artificial conditions takes from 1-1.5 years (Fig. 1). Females oviposited under bark, about 40-60 eggs each time, which were laid in a group. Females were kept in captivity for oviposition 150-350 days between the time of their capture and their deaths. After eclosion at 7-9 days, the larvae do not leave the group immediately until about 7th day post-hatching (Fig. 2A). In our observations, the larvae often hunted other larvae (Fig. 2B), so we improved the rearing methods by separating all larvae to single cups and adding larvae of *Zophobas morio* (Tenebrionidae) and wet fish food as the food source. Both food types were fed upon by the larvae (Figs. 2C; 2D). The larvae defecated cylindrical-like stools (size of stool of last instar larva: diameter: 1-2 mm; length: 13 mm) in the medium. After molt, the larvae will consume the exuviae unless they are disturbed. During the rearing process, larvae were observed to build tunnels in the medium, and some of which chewed on the wood which served as the source of the tunnel material (Fig. 3A). Larvae would stay in these tunnels except hunting or feeding on fish food on the surface. In our test, the larvae used all of the offered media to build pupal cells (Figs. 3B; 3C). The pre-pupa is crutch-like, with the body folded at the 2nd abdominal segment (Fig. 3D). Pupae eclosed after 40-46 days (Fig. 4). The resting period of newly eclosed adults is 60-62 days. Eventually, five male adults were successfully emerged under the rearing conditions mentioned above. (mean of length: 44.3 mm).

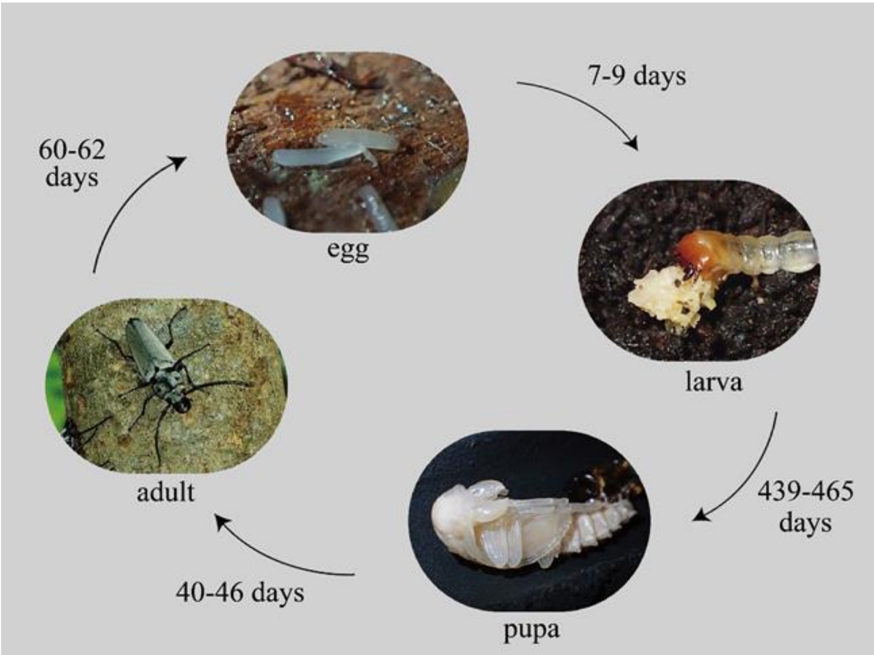

Figure 1. Life cycle of *Trictenotoma formosana* Kriesche, 1919 under artificial conditions.

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Figure 2. Larvae of *Trictenotoma formosana* Kriesche, 1919. A - first-instar larval group; B - larvae of *T. formosana* feeding on conspecific; C - larva of *T. formosana* feeding on a larva of *Zophobas morio*; D - larva of *T. formosana* feeding on wet fish food.

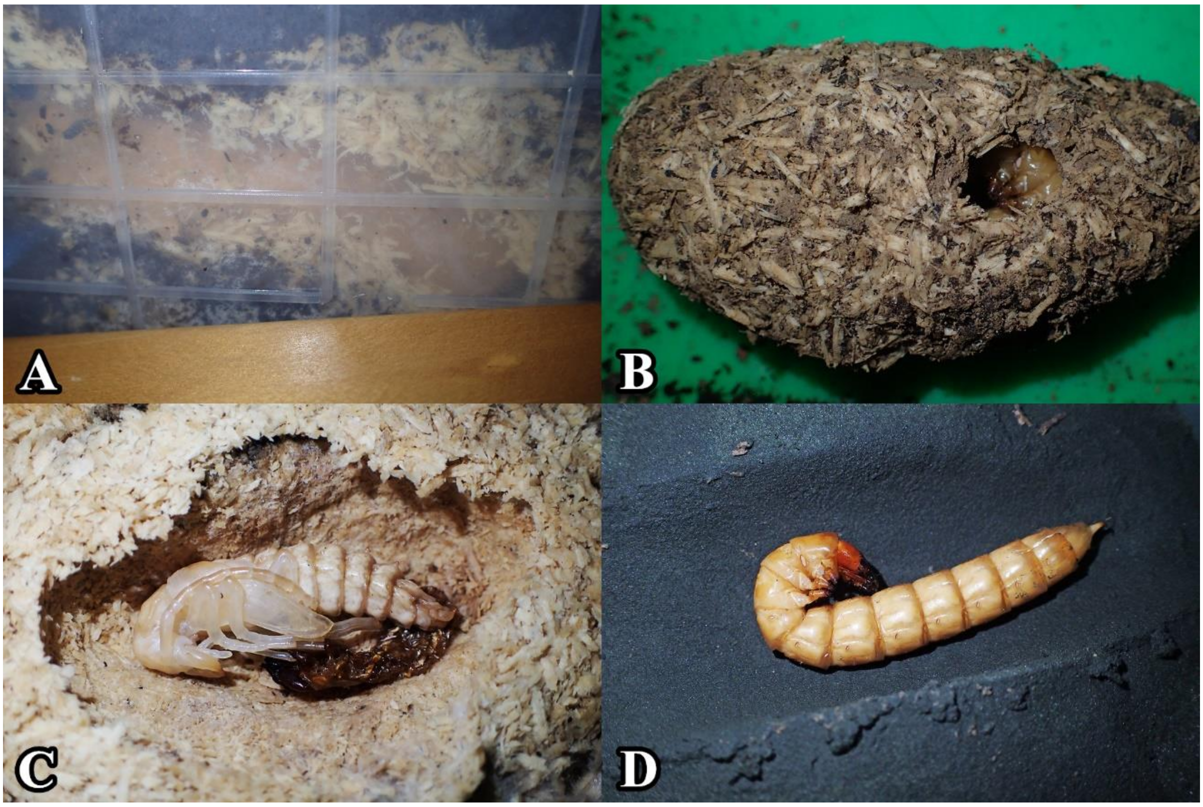

Figure 3. Tunnel, pupal cell, pupa and pre-pupa of *Trictenotoma formosana* Kriesche, 1919. A – larval tunnel constructed from wood; B - pupal cell (the hole in the cell was made by the first author); C - pupa in the pupal cell; D - pre-pupa in artificial pupal cell.

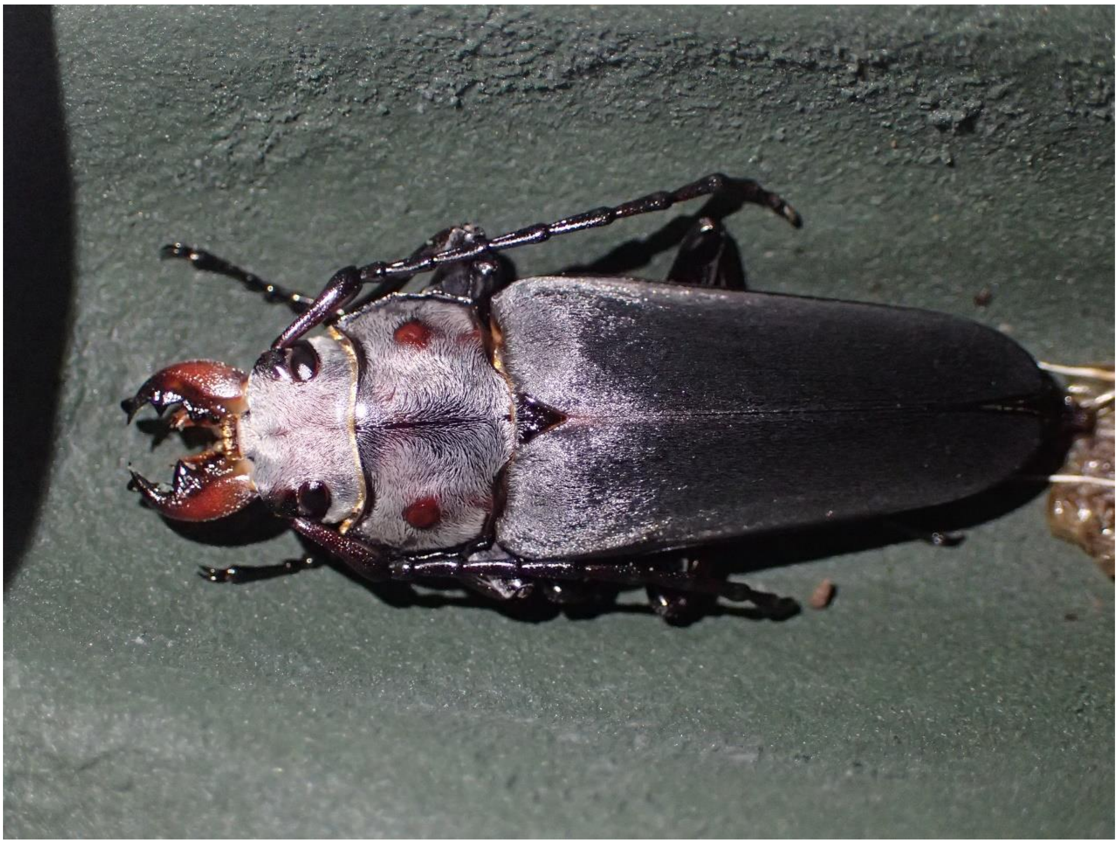

Figure 4. Newly eclosed adult male of *Trictenotoma formosana* Kriesche, 1919.

Natural History

Adult

Adults *T. formosana* were observed from early June to late July, in disturbed, low altitude secondary forests on main island of Taiwan. In our observations, the adults inhabit trunks or branches of the tall trees, often higher than 10 m up on the tree, but also be found occasionally lower down on the tree. In the morning, adults feed on the sap of the tree or mating (Fig. 5) where they co-occurred with Lucanidae, Nymphalidae, Scarabaeidae and Vespidae. We have found adults on various species of trees such as *Cassia fistula* L., *Fraxinus griffithii* C.B. Clarke, *Koelreuteria henryi* Dümmer, *Quercus glauca* Thunb and *Ulmus parvifolia* Jacq. The first author shook the trees and then the adults dropped down on the ground in the evening. Adults are good fliers and have greater activity in the morning. Some individuals still stayed on the trees at night with lower activity, so we can collect them easily. The first author also observed some individuals attracted by light. We did not observe the oviposition behavior in the wild, but only from our observations under artificial conditions. They may oviposit the eggs under bark of dead trees.

Larva

We did not observe larvae in the wild, but an observation of a wild larva was made by another local observer. A larva was found in the root section of a large, upright, dead tree, which was found under 50 cm of the humus and co-occurred with *Dorcus* larvae in low altitude secondary forest. The larva was found in early April, 2006 in Miaoli county; the observer tried to keep it alive in captivity but failed. Although this specimen was not preserved, the size of the larva and photograph of it confirm that it was indeed the larva of *Trictenotoma* (Fig. 6) (Yu, T.-Y., personal communication, January 21, 2019).

Figure 5. Adults of *Trictenotoma formosana* Kriesche, 1919 on a tree trunk, feeding on sap and mating (Photo by Liu, M.-H.).

Figure 6. *Trictenotoma* larva collected by a local observer (Photo by Yu, T.-Y.).

Discussions

Based on the results of our studies, we suggest that *Trictenotoma* larvae should be separated into their own rearing containers to avoid cannibalistic behavior. Though the *Trictenotoma* larvae were found cannibalizing or consuming larvae of *Zophobas morio* or wet fish food, it is still unclear whether they are carnivorous or omnivorous, because of a special example found in our rearing process. The length of male adults in artificial condition is 42.4 ± 6.24 mm (n=5), including a single male which was only 33 mm (Fig. 7). This adult did not feed on any larvae of *Z. morio* or wet fish food after the larval length reached 4 cm. After 9 months, it still built a pupal cell and pupated. We are not sure if it fed on the fermented decayed wood flakes during its life cycle. Despite of our limited sample size, it appears that the lack of feeding on tenebrionid larvae and fish foods caused its smaller in final adult size. In our test, last-instar larvae used various materials to build pupal cells, and the wood seems to be non-essential during the immature stages. We do not know the number of larval instars in *T. formosana* but perhaps there are 8 or 9, because they usually inhabit in medium, feeding on their exuviae after molting. Therefore, the observation of the molting process (and determining how many times it happens) is very difficult. These reasons make the observation of molting moment difficult. Adults of *T. formosana* tend to be diurnal though they were attracted by light such as other Trictenotomidae (Pollock & Telnov, 2010). In our observations, they have lower activity at night. In-depth observations of other species of Trictenotomidae are needed.

Figure 7. The smallest adult male among reared specimens from our studies.

The taxonomic history of Trictenotomidae is complex. Westwood (1848) placed Trictenotomidae near the Cerambycidae in Chrysomeloidea; this concept has also been supported in recent works in which the classification is based only on characteristics of the adult (Ferrer & Droumont, 2003; Droumont, 2006). Trictenotomidae was also treated as a subfamily of Pythidae by Crowson (1981) but no reasons were given for this placement. Watt (1987) proposed that Trictenotomidae, Boridae, and Pythidae should be separate familes, and, in the same work, produced a cladogram based on characteristics of larvae and adults: (Trictenotomidae + (Salpingidae + (Boridae + Pythidae))). A similar cladogram, also based on morphological features of larvae and adults, was published by Pollock (1994) who hypothesized the following relationships among the same familes (with the inclusion of Pyrochroidae): (Trictenotomidae + (Salpingidae + (Boridae + Pythinae + Pilipalpinae + Pyrochroidae))). In a recent paper (Beutel & Friedrich, 2005), a phylogenetic tree of Tenebrionoidea was established based on characteristics of larvae, which supported Trictenotomidae as a sister group of Pythidae. However, this work was based only on the old voucher specimen of *Trictenotoma childreni* described by Gahan (1908) which was old and in poor condition. Kergoat et al. (2014) established a phylogenetic tree based on both mitochondrial gene and nuclear fragments, which supported Salpingidae as the sister group of Trictenotomidae, but Pythidae and Boridae were not included in the analyses. The only published description of a larva of Trictenotomidae is that of Gahan (1908), but the combination of the outdated description and the poor state of preservation preclude its usefulness for modern phylogenetic work. Formal descriptions of the immature stages of *T. formosana* will be published in future studies.

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揭開擬鍬形蟲科的世紀之謎：蓬萊擬鍬形蟲的自然史及人工飼養技術 （鞘翅目： 擬鍬形蟲科）

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摘要: 本篇文章報導臺灣產蓬萊擬鍬形蟲的詳細生物學資訊，涵蓋其自然史、生活史、飼養技術及在人工條件下的行為觀察，為擬鍬形蟲科生物學研究的首篇研究報告。本文探討了幼蟲食性及成蟲習性，也以圖像記錄了進一步的生活史觀察，包括幼蟲群體、成蟲及幼蟲的進食狀況、幼蟲所建造的隧道、土繭及新羽化成蟲。

關鍵字: 擬鍬形蟲科、擬鍬形蟲屬、自然史、人工飼養技術、幼蟲