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The Newly Recorded Fern-spore Feeding Moths in the Genus *Calicotis*, Meyrick 1889 (Lepidoptera: Stathmopodidae) from Taiwan, with Notes on Life History of Three Species

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Three newly recorded species of the genus *Calicotis*, Meyrick 1889 are reported from Taiwan: *C. attiei* (Guillermet, 2011), *C. rotundinidus* Terada, 2016, and *C. exclamationis* Terada, 2016. *C. biserraticola* Terada, 2016 is treated as a junior subjective synonym for *C. attiei* based on both morphological and molecular data. The life history of these three species is presented as well as the first observation of fern-feeding stathmopodid eggs in the world.

Key words: Cuprininae, Ferns, Immature biology, Spore-feeding, Taiwan.

BACKGROUND

The Stathmopodidae (Lepidoptera: Gelechioidae) represent a group of micro moths which can be recognized by the characteristic rosettes of long and rigid bristles on their hind leg (Sinev 2015). Species classification of this family is usually confusing, mainly due to the lack of diagnostic morphological characters (Hodges 1998). Moreover, some species of this family are hard to collect, which often means they are either ignored by many lepidopterists or rarely encountered.

Collections of stathmopodid moths have mainly relied on light traps, so knowledge of immature stages of these moths is poor. Using the comprehensive work on the Japanese fauna of this family by Terada (2016) as a guide, we investigated host plant associations of stathmopodid moths in Taiwan. This strategy proved effective, with some unrecorded stathmopodid moths and new host plant associations being discovered during the investigation.

Calicotis, Meyrick 1889 is one of the fern-feeding genera of Stathmopodidae (Terada 2016). These moths can be diagnosed by a broadened scape, usually termed the eye-cap, on the antenna. This genus is mainly distributed in Asia and Australasia (Meyrick 1889 1922; Lower 1904; Turner 1917; Kasy 1973; Sinev 1988; Guan and Li 2015; Terada 2016), with some sporadic records in Seychelles (Meyrick 1911; Bippus 2020). There are 19 described species in the genus: *Calicotis animula* Meyrick, 1911, *C. attiei* (Guillermet, 2011), *C. biserraticola* Terada, 2016, *C. chrysoptera* Terada, 2016, *C. crucifera* Meyrick, 1889, *C. dilate* Guan & Li, 2015, *C. exclamationis* Terada, 2016, *C. griseella* Sinev, 1988, *C. latebrifica* Terada, 2016, *C. luteella* Sinev, 1988, *C. microgalopsis* Lower, 1904, *C. praeusta* Meyrick, 1922, *C. rhizomorpha* Meyrick, 1927, *C. rotundinidus* Terada, 2016, *C. sialota* Turner, 1917, *C. sublucida* Terada, 2016, *C. triploesta* Turner, 1923, *C. uncinata* Guan & Li, 2015, and *C. xanthopsis* Terada, 2016.

Our host plant survey observed stathmopodids

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previously unrecorded in Taiwan. Of these, three species possess an eye-cap on the first antennomere which is diagnostic of *Calicotis* Meyrick, 1889, a genus not previously recorded in Taiwan. However, after comparing the wing patterns and genitalia of the specimens with all previous known taxa, these three species were identified as *C. attiei* (Guillermet, 2011), *C. routundinidus* Terada, 2016, and *C. exclamationis* Terada, 2016. The life histories of these species were previously unrecorded in Taiwan, but are documented herein. Moreover, the egg of *C. attiei* (Guillermet, 2011) was observed, which represents the first observation of eggs for fern-feeding stathmopodid moths in the world.

We also found that *C. biserraticola* Terada, 2016 is indistinguishable from *Calicotis attiei* (Guillermet, 2011) in wing pattern, genitalia structure, and mitochondrial *Cox 1* gene. Based on this evidence, *C. biserraticola* Terada, 2016 is considered to be a junior subjective synonym of *C. attiei* (Guillermet, 2011) in the present study.

MATERIALS AND METHODS

Morphological examination

Adult moths were reared from immature stages collected from their host plants in Taiwan and Okinawa, Japan (Fig. 1). The detailed collection site information is present in the materials section. Genitalia slides were prepared following procedures described by Common (1990). Terminology of genitalia follows Klots (1970) and Koster and Sinev (2003), and terminology of wing patterns follows Koster and Sinev (2003). Specimens were deposited into the Biodiversity Research Museum, Academia Sinica, Taiwan (BRMAS), and National Taiwan Normal University, Taiwan (NTNU).

Molecular analysis

Cox 1 (CO1) barcodes of 3 superficially similar taxa were examined for comparison, with examples including two individuals of *C. attiei* from Taiwan, one *C. biserraticola* from Japan, and one

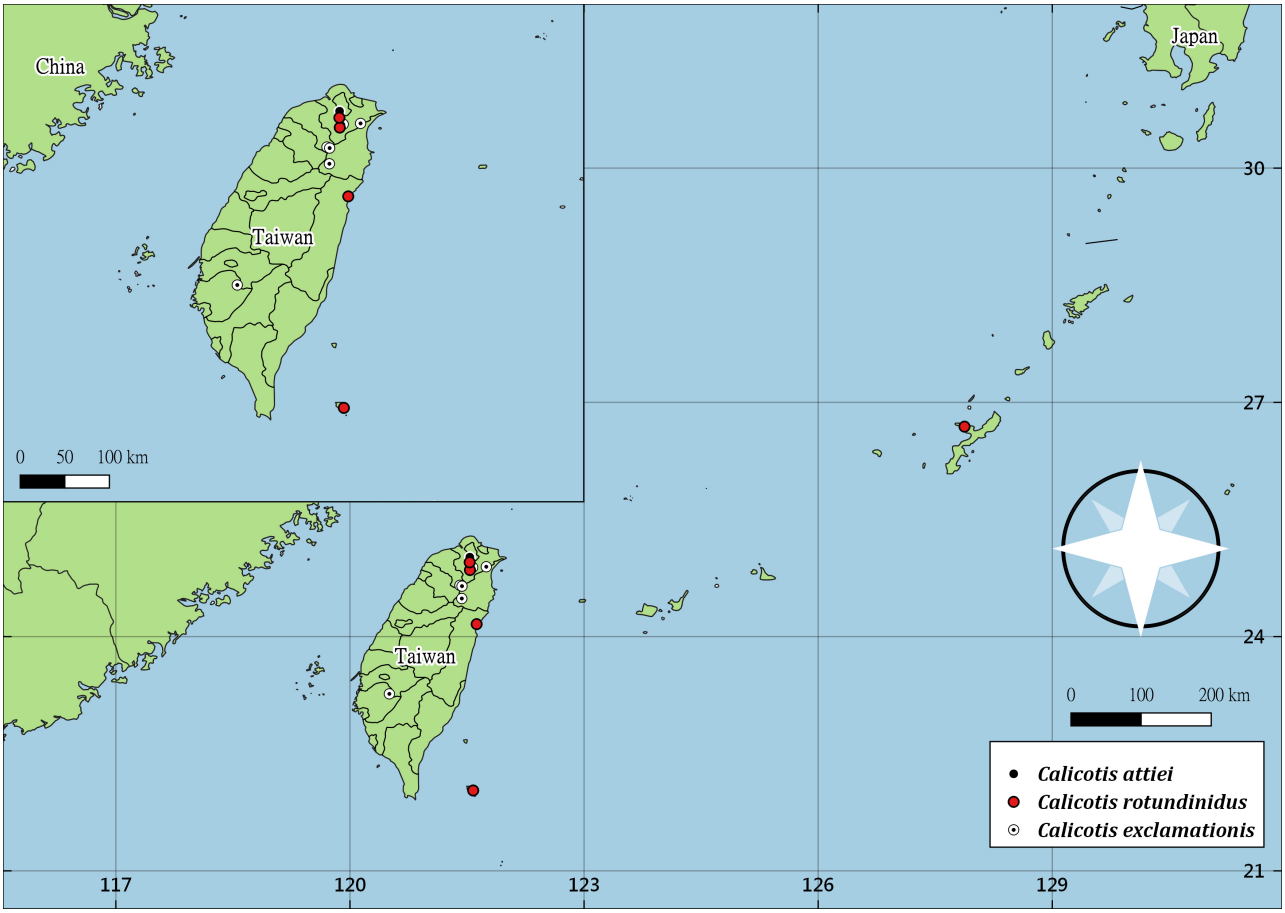


Fig. 1. Collecting sites of *Calicotis* used in the present studies.

C. crucifera from New Zealand. Total DNA of these four samples was extracted with NautiaZ Tissue DNA Mini Kit (Nautia Gene, Taipei, Taiwan) from the specimens' abdomens. The abdomens were used for genitalia dissection and slide preparation after the extraction process. The CO1 fragments were amplified with one set of two universal primers: LCO1490 5'-GGTCAACAAATCATAAAGATATTGG-3' and HCO2198 5'-TAAACTTCAGGGTGACCA AAAAATCA-3' (Folmer et al. 1994), or COIP1 5'-TTGATTTTTTGGTCAYCCWGAAGT and COIR4 5'-CCWVYTARDCCTARRAARTGTTG (Bucheli and Wenzel 2005). PCR was performed by using Illustra^{TM}puReTaq Ready-To-Go Beads (GE Healthcare, United Kingdom) with 1μl of forward and reverse primer (for a total of 2 μl), 2 μl of DNA and 21 μl of ddH_2O. The thermal cycler was set with the initial denaturation at 94℃ for 2 min, followed by 35 cycles of denaturation at 94℃ for 20s, annealing at 50℃ for 40s and extension at 72℃ for 1 min. The final extension was at 72℃ for 10 min. The NautiaZ Gel/PCR DNA purification Mini Kit (Nautia Gene, Taipei, Taiwan) was used to clean up the PCR product. The purified PCR products were sequenced by the Institute of Biomedical Science, Academia Sinica (Taiwan). The DNA sequences obtained were edited using the CLUSTALW multiple alignment program in BIOEDIT v7.0 (Hall 1999). The calculation of pairwise distances between four individuals was performed using the Kimura 2-parameter model in MEGA XI (Tamura et al. 2021). All sequences were deposited into GenBank, and the detailed information of the sequences were presented in table 1.

RESULTS

Synonymic treatment on *Calicotis attiei* (Guillermet, 2011)

Recently, *Stathmopoda attiei* Guillermet, 2011 was transferred to *Calicotis* based on genitalia and habitus by Bippus (2020). Also, *C. cuspidate* Guan & Li, 2015 was treated as synonymous to *C. attiei* (Guillermet, 2011) based on the similarity in morphological and genitalia characters in the same study. Here, after comparing the original descriptions of *C. attiei* (Guillermet, 2011) and *C. biserraticola* Terada, 2016, we found that these two species were similar in nearly all characters of wing pattern and genital morphology.

Moreover, we applied the molecular analysis to examine the CO1 genetic distance among the *C. attiei* (Guillermet, 2011) in Taiwan, *C. biserraticola* Terada, 2016 in Japan, and *C. crucifera* Meyrick, 1889 in New Zealand. The reason why we also included *C. crucifera* in this comparison is we wanted to present the genetic distance within and between the species form the same genus. Also, *C. crucifera* is the type species of this genus. The genetic distance between the *C. attiei* (Guillermet, 2011) in Taiwan and *C. biserraticola* Terada, 2016 in Japan was zero, and the genetic distance between *C. crucifera* and the other two species ranged from 0.112–0.116 (Table 2). Consequently, both morphological and molecular data support the conspecificity of *C. attiei* (Guillermet, 2011) and *C. biserraticola* Terada, 2016. We thus treat *C. biserraticola* Terada, 2016 as a subjective junior synonym of *C. attiei* (Guillermet, 2011) herein (new synonymy).

TAXONOMY

Family Stathmopodidae Meyrick, 1913
Subfamily Cuprininae Sinev, 2015
Calicotis Meyrick, 1889

Calicotis Meyrick, 1889: 170. Type species: *Calicotis crucifera* Meyrick, 1889, by monotypy.

Diagnosis: According to Meyrick (1889), species of *Calicotis* can be diagnosed by the following combination of characters: Head with smooth scale covering; antenna not ciliated or very shortly ciliated in male, basal antennomere broadly dilated, excavated beneath to form eyecap, rough-scaled on posterior edge, without pecten; labial palp long, curved, ascending, with smooth scales covering; forewing lanceolate; hindwing narrowly lanceolate; mid-tibia with long

Table 1. GenBank accession number and detailed information for each sequence

GenBank accession number	Species	Average size of the sequence	Collection sites
LC717496	*Calicotis biserratocola*	1098 b.p.	JAPAN: Ryukyu, Okinawa, Yonaguni Is.
LC717497	*Calicotis attiei*	658 b.p.	TAIWAN: Hulian, Shioulin, Gekou
LC717498	*Calicotis attiei*	658 b.p.	TAIWAN: Taipei, Daan, NTU Campus
LC717499	*Calicotis crucifera*	643 b.p.	NEW ZEALAND: Auckland, Rodney, Puhoi

projecting spines distally; posterior-tibia with dense long bristles; posterior-tarsus with whorls of long projecting bristles at apex of all tarsomeres. Guan and Li (2015) and Terada (2016) emphasized the dilated scape, namely the eye-cap *sensu* Meyrick (1889), as the diagnostic feature unique to the genus. *Calicotis* is superficially similar to *Pachyrhabda* Meyrick, 1897 in appearance, but according to Guan and Li (2015) it can be distinguished by the presence of the eye-cap structure and the orientation of male abdominal tergite spines. In *Calicotis* species, these spines are arranged in a broad inverted V-shape, whereas in *Pachyrhabda* such spines are arranged in a broadly arched shape.

Calicotis attiei **(Guillermet, 2011)**

(Figs. 2–8, 23–26, 35)

Stathmopoda attiei Guillermet, 2011: 186, photo. 9, figs. 8–9. Type locality: La Réunion.
Calicotis cuspidata Guan & Li, 2015: 5, figs. 8, 12, 16. Type locality: China.
Calicotis biserraticola Terada, 2016: 128, figs. 170–174, pl. VIII-3,4, XVIII-2. Type locality: Japan. Syn. Nov.

Material examined: 4 ♂, 1 ♀, Taiwan: Hualian, Xiulin, Dekalun, ca 300 m, 22 Feb 2018, reared from *Nephrolepis biserrata*, emg. 11–18 Mar 2018, Y. F. Hsu Coll. (BRMAS, NTNU). 5 ♂, 10 ♀, Taiwan: Hualian, Xiulin, Gekou, ca 270 m, 9 Jul 2018, reared from *N. biserrata*, emg. 23–30 Jul 2018. Y. F. Hsu Coll. (1 ♀, Gen. Prep. ZYS-0086, NTNU. Gen. Prep. ZYS-0044, NTNU). 11 ♂, 9 ♀, Taiwan: Taipei, Daan, Herbarium of National Taiwan University, 16 Nov 2019, reared from *Microsorum scolopendria*, emg. 7–26 Dec 2019. Z. Y. Shen, Y. C. Wang Coll. (BRMAS).

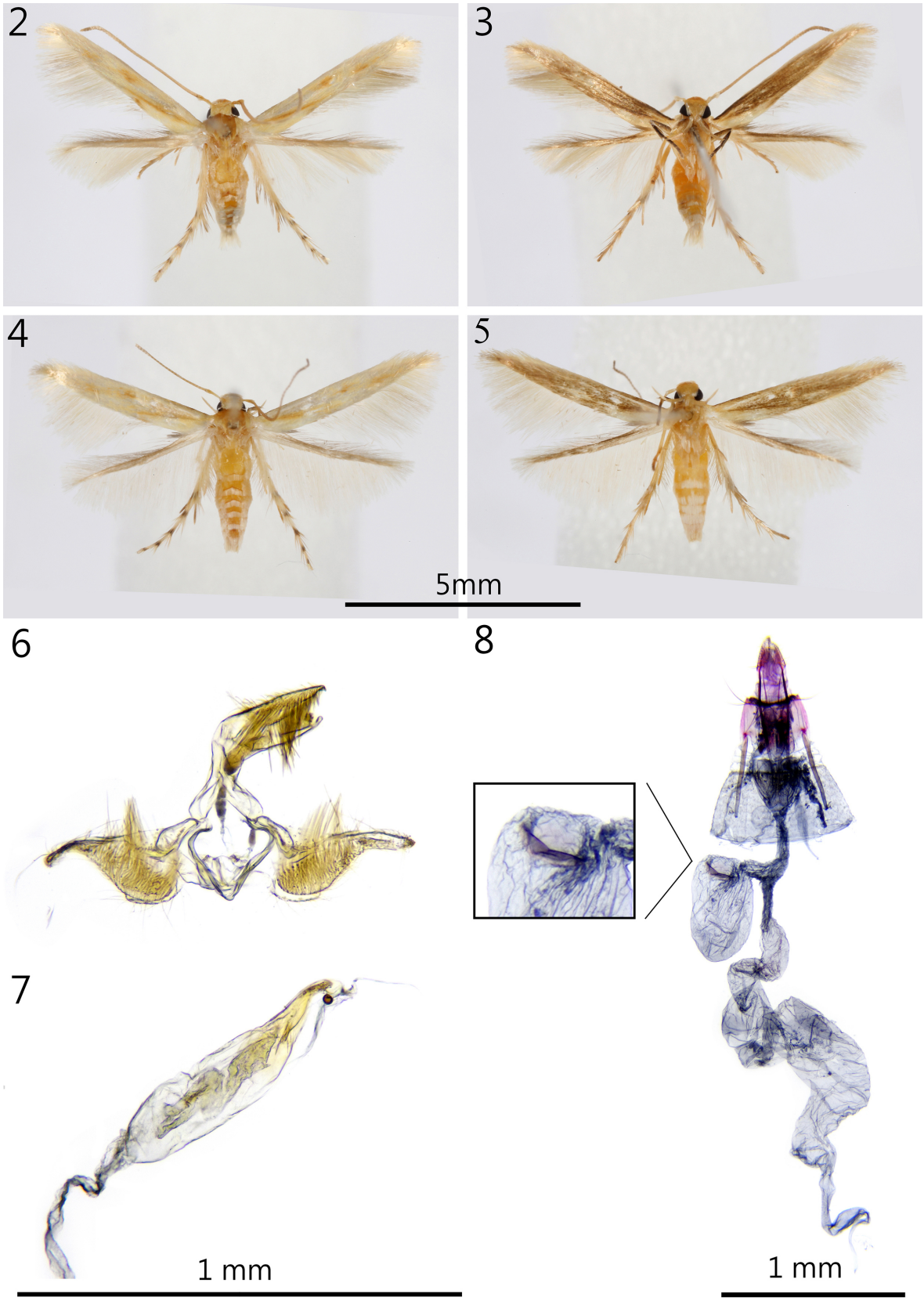
Description: Male (Figs. 2–3). Forewing length 3.02–4.23 mm (n = 9). Head: Frons silvery white. Vertex creamy white. Occiput creamy white, with pale brown streak at anterior margin. Antenna with scape broadly dilated, creamy white, flagellum creamy white. Labial palp slender, long, strongly upcurved, dorsally creamy white, ventrally white. Thorax: Surface covered by creamy white scales. Legs: Fore and middle legs white, foretibia and foretarsus covered by fuscous scales dorsally, mesotibia bearing a pair of spurs distally, with outer spur approximately 1/3 length of inner spur. Hind leg white, metatibia overlaid with creamy white bristles, metatarsus with each tarsomere bearing a whirl of creamy white bristles, fuscous scales appearing at the joints of each tarsomere; metatibia bearing two pairs of white spurs at both proximal and distal joints, proximal spurs with outer one approximately 1/3 length of inner one, distal spurs with outer one approximately the same length as inner one. Forewing: Dorsally ground color creamy white with two ocherous streaks, one stretching from near base to middle of CuP and the other stretching from the discal cell to near apex, cilia white; ventrally silvery grey. Hindwing: Ground color silvery grey, cilia white. Abdomen: White, anal tuft present.

Female (Figs. 4–5): Forewing length 3.37–3.94 mm (n = 11). Similar to male but lacking anal tuft in abdomen.

Male genitalia (Gen. Prep. ZYS-0044, NTNU, Figs. 6–7): Uncus elongate triangular, apex slightly down-curved, acute, laterally setose. Gnathos elongate triangular, approximately the same length as uncus, with more sharply angled apex than uncus. Valva nearly pediform, pointed apically; costa broad at base, slightly narrow to apex, costal ring developed,

Table 2. Pairwise distances of Cox1 sequences between samples of *Calicotis attiei* (Taiwan), *C. biserraticola* (Japan), and *C. crucifera* (New Zealand)

	Calicotis attiei (Taiwan Hualien) (LC717497)	*C. attiei* (Taiwan Taipei) (LC717498)	*C. biserraticola* (Japan) (LC717496)	*C. crucifera* (New Zealand) (LC717499)
C. attiei (Taiwan Hualien) (LC717497)				
C. attiei (Taiwan Taipei) (LC717498)	0.000			
C. biserraticola (Japan) (LC717496)	0.000	0.000		
C. crucifera (New Zealand) (LC717499)	0.116	0.116	0.112	



Figs. 2–8. Adult specimens and genitalia of *Calicotis attiei*. 2–3, Male specimen, TAIWAN: Hualian, Shioulin, Gekou; 4–5, Female specimen, TAIWAN: Hualian, Shioulin, Gekou; 6–7, Male genitalia; 8, Female genitalia. Scale bars: 2–5 = 5 mm; 6–7 = 1 mm; 8 = 1 mm.

heavily sclerotized; sacculus S-shaped; cucullus longer than uncus, with numerous setae on inner surface. Saccus approximately 3/4 length of uncus. Phallus stout, approximately 2x as long as uncus, with weakly sclerotized wrinkles on vesica, cornutus absent.

Female genitalia (Gen. Prep. ZYS-0086, NTNU, Fig. 8): Papillae anales slightly longer than wide. Apophyses posteriores approximately 1.3x as long as apophyses anteriores. Ostium bursae funnel-shaped, with prominent sublateral fold. Corpus bursae with large signum, broadly V-shaped, situated at 1/4 of corpus bursae; bulla with ductus seminalis, a number of small spines present at apex of ductus seminalis.

Diagnosis: This species can be distinguished from congeners by the presence of two ocherous streaks on the forewing, one stretching from near the base to middle of CuP and the other from the discal cell to apex; and in male genitalia by the nearly pediform valva with a pointed apex, which is unique among *Calicotis*.

Host plants: *Nephrolepis biserrata* (Sw.) Schott., 1834 (Nephrolepidaceae), *Christella acuminata* (Houtt.) H. Lév. (Thelypteridaceae) (Terada 2016), and *Microsorum scolopendria* (Burm. f.) Pic. Serm., 1973 (Polypodiaceae) (Bippus 2020).

Biology: The eggs (Fig. 35) are laid in the sporangiospores of the hostplant, and they are easily confused with the surrounding sporangia. They are ellipsoid with a pentagonal pattern on the surface. Larvae (Fig. 24) were found in February, July and November. The larvae fed on *N. biserrata* and *P. scolopendria* in Taiwan. They constructed silken galleries (Fig. 23) mixed with fern spores and frass on the underside of the host plant. The larvae lived inside a shelter and fed on the spores until pupation. The cocoons (Fig. 25) were oval in shape. Adult moths (Fig. 26) emerged about half to one month after pupation without diapause, suggesting that this species may be multivoltine.

Distribution: Réunion (Guillermet 2011), China (Guan and Li 2015), Japan (Terada 2016), and Taiwan.

Calicotis rotundinidus **Terada, 2016**

(Figs. 9–15, 27–30)

Calicotis rotundinidus Terada, 2016: 131, figs. 175–179. Type locality: Japan.

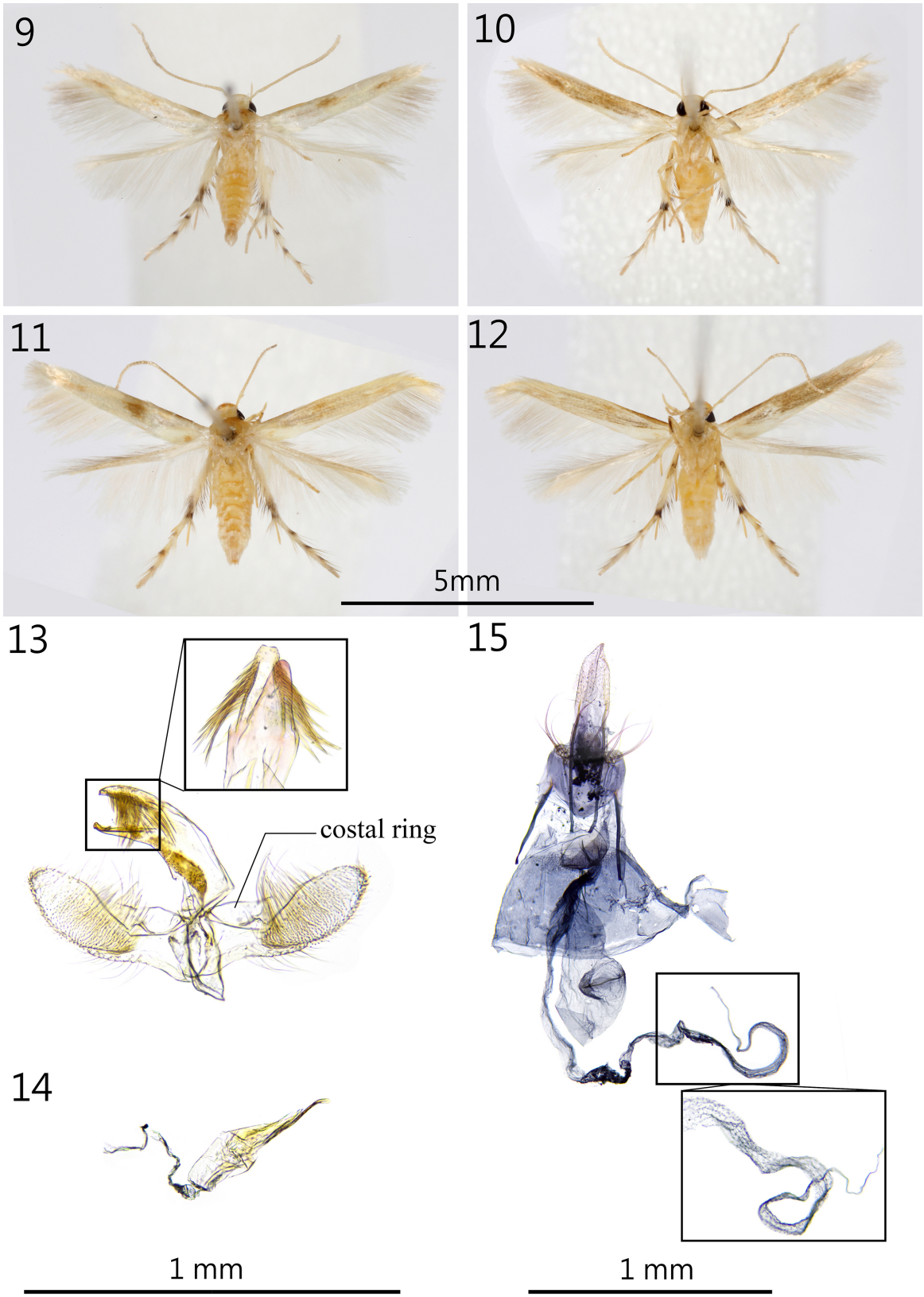
Material examined: 2 ♂, 2 ♀, Taiwan: Hualian, Xiulin, Gekou, ca 270 m, 14 Jun 2018, reared from *Asplenium setoi*, emg. 15–29 Jul 2018, Y. F. Hsu Coll. (1 ♂, Gen. Prep. ZYS-0045, NTNU). 3 ♂, 3 ♀, Taiwan: New Taipei City, Wulai, Bauqing temple, ca 600 m, 30 Sep 2018, reared from *Asplenium setoi*, emg. 29 Oct–05 Nov 2018, Z. Y. Shen, Y. Y. Lu Coll. (BRMAS). 1 ♂, 1 ♀, Taiwan: New Taipei City, Xindian, Hemeishan, ca 150 m, 29 Nov 2019, reared from *A. nidus*, emg. 25 Dec 2019, Z. Y. Shen, C. W. Huang, Y. C. Wang Coll. (1 ♀, Gen. Prep. ZYS-0088, NTNU). 3 ♂, 1 ♀, Taiwan: Taidong, Lanyu, Yongxing farm, 21 Mar 2020, reared from *A. nidus*, emg. 6–21 Apr, Y. F. Hsu Coll. (BRMAS, NTNU). 3 ♀, Japan: Okinawa, Kunigami, Motobu, Ishikawa, 27 Jun 2019, reared from *A. setoi*, emg. 16–21 Jun 2019, Z. Y. Shen Coll. (BRMAS).

Description: Male (Figs. 9–10). Forewing length 3.18–3.58 mm (n = 5). Head: Frons silvery white. Vertex silvery white. Occiput white. Antenna with scape broadly dilated, white, flagellum creamy white. Labial palp slender, long, strongly upcurved, white. Thorax: Surface covered by creamy white scales, with fuscous streak on the anterior margin, with a pair of fuscous dots on posterior part, tegula creamy white, with pale brown block on approximately 1/2 of tegula. Legs: Fore and middle legs white, foretibia covered by fuscous scales dorsally, mesotibia bearing a pair of spurs distally joint, with outer spur approximately 1/3 length of inner spur; hindleg white; metatibia overlaid with creamy white bristles, with a whirl of fuscous bristles at distal joint, metatarsus with each tarsomere bearing a whirl of creamy white bristles, fuscous scales at joints of each tarsomere; metatibia bearing two pairs of creamy white spurs at both proximal and distal joints, proximal spurs with outer one approximately 1/3 length of inner one, distal spurs with outer one approximately the same length as inner one. Forewing: Dorsally ground color creamy white, costa fuscous on basal 1/3, a brown spot present near base of dorsum, dark brown fascia at 2/5 of wing, extended towards but not reaching costa, a brown streak present near apex, cilia white; ventrally silvery grey. Hindwing: Ground color creamy white, cilia white. Abdomen: White, anal tuft present.

Female (Figs. 11–12): Forewing length 2.73–3.36 mm (n = 8). Similar to male but lacking anal tuft in abdomen.

Male genitalia (Gen. Prep. ZYS-0045, NTNU, Figs. 13–14): Uncus stout, apically slightly down-turned, with shallowly bilobate apex, setose laterally. Gnathos elongat triangular, apex slightly upcurved, nearly the same length as uncus, with blunt apex. Valva with round apex; costa thicker than sacculus, costal ring developed, heavily sclerotized. Sacculus slightly sinuate; cucullus nearly oval, approximately 2x as long as uncus, with numerous setae on inner surface; saccus approximately the same length as uncus. Phallus stout, approximately 3x as long as uncus, with weakly sclerotized wrinkles on vesica, cornutus absent.

Female genitalia (Gen. Prep. ZYS-0088, NTNU, Fig. 15): Papillae anales longer than wide. Apophyses posteriores approximately 1.5x as long as apophyses



Figs. 9–15. Adult specimens and genitalia of *Calicotis rotundinidus*. 9–10, Male specimen, TAIWAN: Hulian, Shioulin, Gekou; 11–12, Female specimen, TAIWAN: New Taipei City, Wulai, Bauching temple; 13–14, Male genitalia; 15, Female genitalia. Scale bars: 9–12 = 5 mm; 13–14 = 1 mm; 15 = 1 mm.

anteriores. Ostium bursae with prominent sublateral fold. Corpus bursae with large signum, bar-shaped, situated in middle of corpus bursae; bulla assimilated with ductus seminalis; many small spines present at apex of ductus seminalis.

Diagnosis: This species can be recognized by a pair of brown dots on the metascutum and by the forewing pattern: costa dark brown on basal 1/3, brown spot present near base of dorsum, dark brown fascia at 2/5 of wing, extended towards but not reaching costa, a brown streak near apex. Genitalia of this species can be distinguished by the bilobate apex of uncus, sublateral folds on the ostium bursae and the bar-shaped signum.

Host plants: *Asplenium antiqum* Makino, 1929 (Terada 2016), *A. setoi* N. Murak & Seriz, 1999, and *A. nidus* L., 1753 (Aspleniaceae).

Biology: Larvae (Fig. 27) were found in May, June, September and November. The larvae fed on *A. setoi* and *A. nidus* in Taiwan. They constructed suboval shelters (Fig. 28) composed of a mixture of fern spores and frass on the underside of the host plant. The larva lives inside the shelter and feeds on the spores until pupation. The cocoon (Fig. 29) is spindle shaped. Adult moths (Fig. 30) emerged about one to one and a half month after pupation without diapause, suggesting that this species is probably multivoltine.

Distribution: Japan (Terada 2016) and Taiwan.

Calicotis exclamationis Terada, 2016

(Figs. 16–22, 31–34)

Calicotis exclamationis Terada, 2016: 134, figs. 180–184. Type locality: Japan.

Material examined: 3 ♂, 2 ♀, Taiwan: New Taipei City, Pinglin, Jianshanhu, ca 500 m, 15 Jan 2018, reared from *Neolepisorus fortunei*, emg. 19 Feb–9 Mar 2018, Z. Y. Shen Coll. (1 ♂, Gen. Prep. ZYS-0046, NTNU). 1 ♂, 1 ♀,Taiwan: Yilan, Yuanshan, Siji, ca 700 m, 21 Mar 2018, reared from *N. fortunei*, emg. 21–23 Apr 2018, Z. Y. Shen, Y. Y. Lu Coll. (BRMAS). 1 ♂,Taiwan: New Taipei City, Xindian, Sikanshui, ca 500 m, 22 Mar 2018, reared from *N. fortunei*, emg. 15 Apr 2018, Z. Y. Shen, Y. M. Hsu, C. J. Chang Coll. (BRMAS). 1 ♂,Taiwan: Tainan, Dongshan, Kantoushan, ca 600 m, 18 Sep 2018, reared from *Colysis wrightii*, emg. 8 Oct 2018, Y. F. Hsu Coll. (BRMAS). 1 ♂, 2 ♀, Taiwan: Taoyuan, Fuxing, Xuanyuan, ca 850 m, 6 Apr 2019, reared from *N. fortunei*, emg. 28 Apr 2019, Y. F. Hsu Coll. (1 ♀, Gen. Prep. ZYS-0087, NTNU). 2 ♂, 1 ♀, Taiwan: Taoyuan, Fuxing, Sileng, ca 1130 m, 12 Feb 2020, reared from *Microsorum brachylepis*, emg. 6–21 Apr 2020, Z. L. Chen, C. W. Huang Coll. (BRMAS).

Description: Male (Figs. 16–17). Forewing length 3.33–4.12 mm (n = 9). Head: Frons silvery white. Vertex white. Occiput white. Antenna with scape broad, creamy white, flagellum creamy white; Labial palp slender, long, strongly upcurved, creamy white. Thorax: Surface white, with fuscous streak on anterior margin, with a pair of fuscous dots on metascutum, tegula creamy white. Legs: Fore and middle legs white, foretibia covered by fuscous scales dorsally, mesotibia bearing a pair of spurs at distal joint, with outer spur approximately 1/3 length of inner spur; hindleg white, tibia overlaid with white and fuscous bristles; metatarsus with each tarsomere bearing a whirl of white bristles, fuscous scales at the joints of each tarsomere; metatibia bearing two pairs of creamy white spurs at both proximal and distal joints, proximal spurs with outer one approximately 1/3 length of inner one, distal spurs with outer one approximately the same length as inner one. Forewing: Dorsally ground color white, ocherous fascia at 1/2 of cell, an ocherous fascia near apex. cilia whitish-fuscous, ventrally silvery grey, cilia ocher. Hindwing: Ground color silvery grey, cilia ocher. Abdomen: White, anal tuft present.

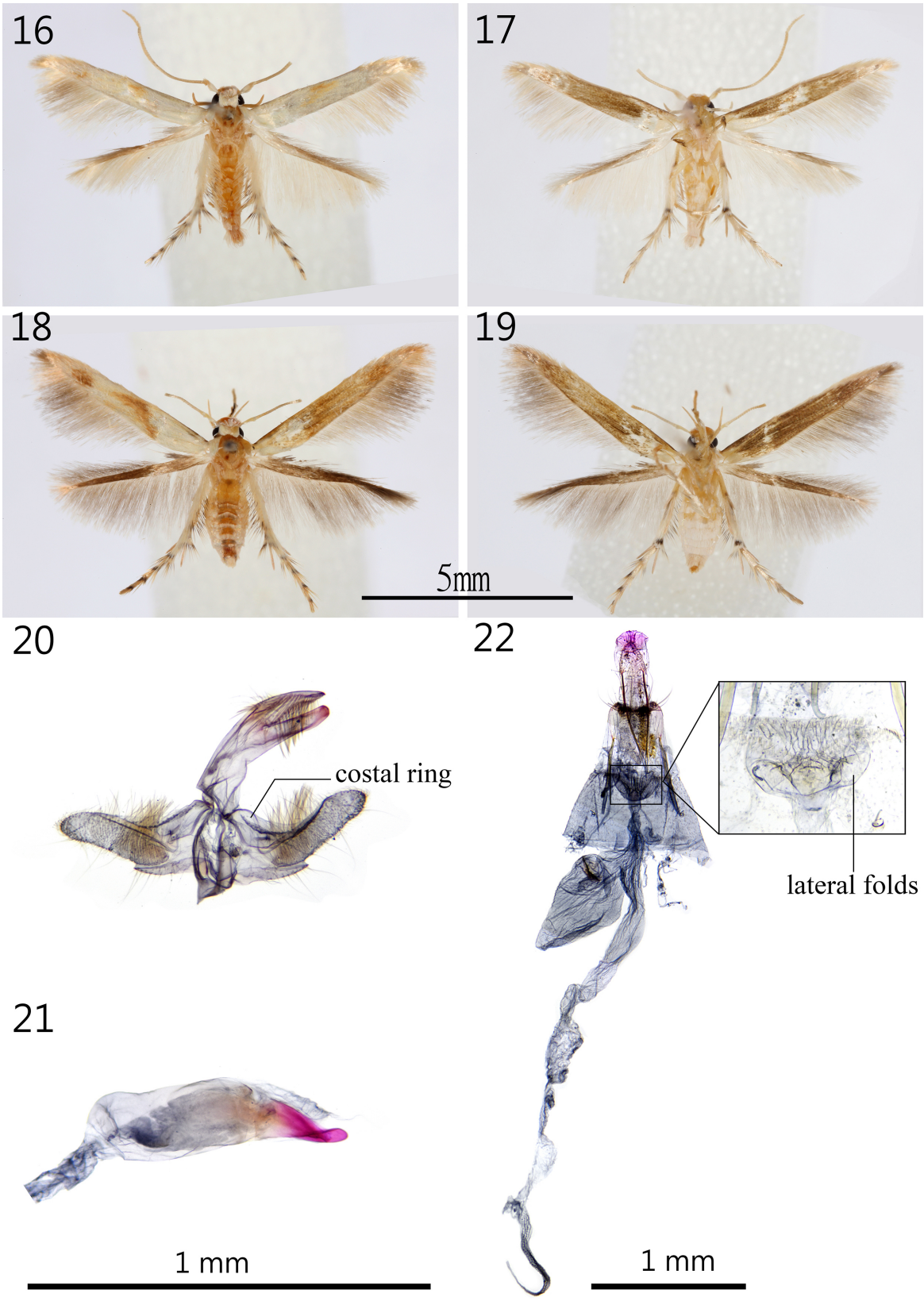
Female (Figs. 18–19): Forewing length 3.64–4.56 mm (n = 6). Similar to male except abdomen without anal tuft.

Male genitalia (Gen. Prep. ZYS-0046, NTNU, Figs. 20–21): Uncus slender, apically slightly down-turned, setae present laterally. Gnathos tongue-shaped, slightly longer than uncus, with round apex in ventral view. Valva with round apex; costa thicker than sacculus, costal ring developed, heavily sclerotized; sacculus broad at base with acute apex distally; cucullus oblong, approximately 1.5x as long as uncus, with numerous setae on inner surface. Saccus approximately half length of uncus. Phallus stout, approximately 4x as long as uncus, with weakly sclerotized wrinkles on vesica, cornutus absent.

Female genitalia (Gen. Prep. ZYS-0087, NTNU, Fig. 22): Papillae anales slightly longer than wide. Apophyses posteriores approximately 1.5x as long as apophyses anteriores. Ostium bursae with prominent oblique sublateral fold. Corpus bursae with large subtriangular signum, situated at 1/5 of corpus bursae; bulla assimilated with ductus seminalis; many small spines presented at the apical of ductus seminalis.

Diagnosis: This species can be recognized by a pair of dark brown dots on the metascutum, and the forewing pattern: fuscous fascia at 1/2 of wing, extended towards but not reaching costa, a fuscous fascia present near apex. In the genitalia: the cucullus is oblong, and oblique lateral folds are present near the anterior margin of the ostium bursae.

Host plants: *Asplenium scolopendrium* L., 1753 (Aspeniaceae), *Plagiogyria euphlebia* (Kunze)



Figs. 16–22. Adult specimens and genitalia of *Calicotis exclamationis*. 16–17, Male specimen, TAIWAN: New Taipei City, Pinglin, Jianshanhu; 18–19, Female specimen, TAIWAN: Taoyuan, Fuxing, Shiuanyuan; 20–21, Male genitalia; 22, Female genitalia. Scale bars: 16–19 = 5 mm; 20–21 = 1 mm; 22 = 1 mm.

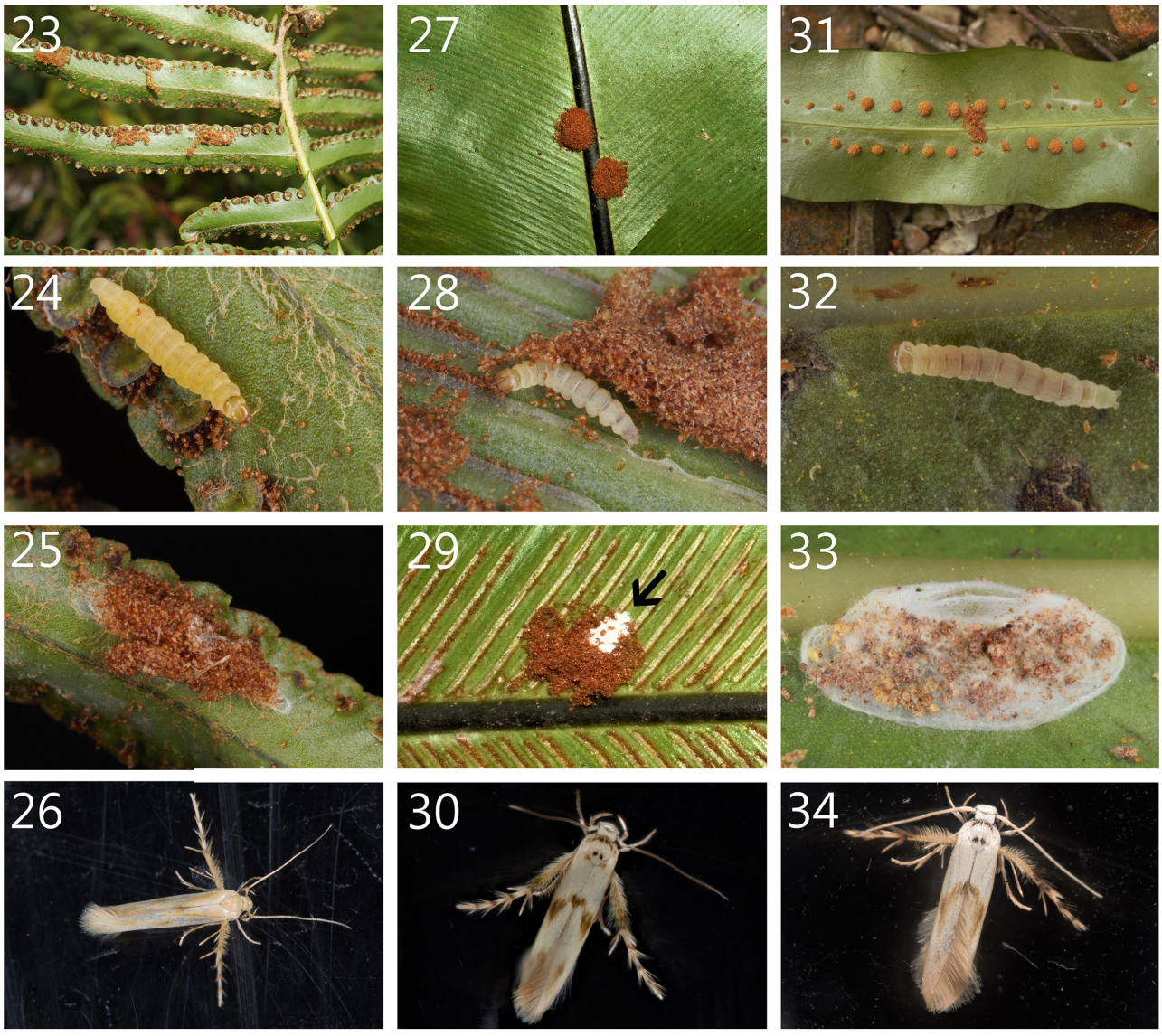
Mett., 1858 (Plagiogyriaceae), *Cyrtomium fortunei* J. Sm., 1866 *Polystichum polyblepharon* (Roem. Ex Kunze) C. Presl, 1851 (Dryopteridaceae), *Athyrium decurrentialatum* (Hook.) var. *decurrentialatum* (Hook.) Copel., 1909 (Athyriaceae), *Coniogramme intermedia* Heiron., 1916, *Pteris terminalis* Wall. Ex J. Agardh var. *fauriei* (Christ) Ebihara & Nakato (Pteridaceae) (Sawamura et al., 2009), *Colysis wrightii* (Hook.) Ching, 1933, *Microsorum brachylepis* (Baker) T. Nakaike, 1981 and *Neolepisorus fortunei* (T. Moore) L. Wang (Polypodiaceae).

Biology: Larvae (Fig. 31) were found nearly throughout year. The larvae fed on *N. fortunei*, *C. wrightii* and *M. brachylepis* in Taiwan. They constructed irregularly shape shelters (Fig. 32) along the sporangiospores on the underside of the host plant. The larvae lived inside the shelter and fed on the spores until pupation. The cocoons (Fig. 33) were oval shaped. Adult moths (Fig. 34) emerged about one month after pupation without diapause, suggesting that this species may be multivoltine.

Distribution: Japan (Terada 2016) and Taiwan.

Key to species of *Calicotis* in Taiwan

1. Thorax with a pair of contrasty fuscous dots along posterior



Figs. 23–34. Immatures and adults of *Calicotis* species from Taiwan. 23, Immature artifacts of *C. attiei* on *Nephrolepis biserrata*. 24, Larva of *C. attiei*. 25, Cocoon of *C. attiei.* 26, Adult resting, photo of *C. attiei*. 27, Immature artifacts of *C. rotundinidus* on *Asplenium austalasicum*. 28, Larva of *C. rotundinidus*. 29, Cocoon of *C. rotundinidus*. 30, Adult resting, photo of *C. rotundinidus*. 31, Immature artifacts of *C. exclamationis* on *Neolepisorus fortune*. 32, Larva of *C. exclamationis*. 33, Cocoon of *C. excalamationis*. 34, Adult resting, photo of *C. excalamationis.*

margin (metascutum) (Figs. 30, 34) 2
2. Thorax uniformly pale (Fig. 26) ..... *C. attiei*
3. Forewing with brown dot near base of dorsum (Fig. 30). Uncus apex bilobate; cucullus oval ..... *C. rotundinidus*
4. Forewing without dot near base (Fig. 34). Uncus apex simple, acute; cucullus oblong ..... *C. exclamationis*

DISCUSSION

Calicotis attiei (Guillermet, 2011) show a wide distribution pattern, ranging from Japan, southern China and Taiwan to the Malagasy Region (Réunion Island), but their morphological features are uniform across their vast geographical range.

In the Malagasy Region, the species was recorded feeding on the spores of several introduced fern species (*e.g.*, *Microsorum scolopendria*) (Bippus, 2020), suggesting their presence may be the result of anthropogenic activities. On the other hand, some studies have demonstrated that tiny insects may have significant dispersal ability by wind owing to their bristle-like wing structure (Chapman et al. 2002; Farisenkov et al. 2022). *Calicotis* moths have narrow, bristle-like wings, and the host plants of *C. attiei* are also distributed around the world in tropical and subtropical regions. These facts suggest *C. attiei* may be subject to passive dispersal, colonizing widely disjunct areas without showing differentiation.

CONCLUSIONS

In the present study, we presented three fern-feeding species, *C. attiei*, *C. rotundinidus*, and *C. exclamationis*, newly recorded from Taiwan, and documented the life history of each species. We also treated *C. biserraticola* as a junior subjective synonym to *C. attiei* based on morphological and molecular data.

Fig. 35. Eggs of *Calicotis attiei* (blue arrows) on the sporangiospores of *Microsorum scolopendria*. Image by Masahiko Tanahashi. Scale bar = 1 mm

Moreover, the photo of the eggs of *C. attiei* on the sporangiospores of the host fern is the first image of live eggs of Cuprininae in the world. Because of their small size, Microlepidoptera are poorly understood in Taiwan and deserve greater attention as an important component of biodiversity.

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Competing interests: The authors declare that they have no conflict of interests.

Availability of data and materials: The specimens are deposited in the collection of Biodiversity Research Museum, Academia Sinica, Taiwan (BRMAS), and National Taiwan Normal University, Taiwan (NTNU). The DNA sequences have been deposited into the GenBank database.

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Ethics approval consent to participate: Not applicable.

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