Redescription of *Euterpnosia varicolor*, and Description of Two New Species of Cicadas from Taiwan (Hemiptera: Cicadidae)

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Abstract. After examining topotypic specimens of *Euterpnosia varicolor* Kato, I found that a new species is misidentified and described as *E. varicolor* in the most recent review of Cicadidae from Taiwan. I herein redescribed *E. varicolor* basing on topotypic specimens and also described the new species, *E. alpina*, and another allied new species, *E. madawdawensis*, from Taiwan. The membranous vesica and sclerotized projections on the apical part of aedeagus were described and proven to be reliable for identifying these three species. I also analyzed and characterized the distinct calling song of each species. After the taxonomic problems of *E. varicolor* were discussed, a neotype of *E. varicolor* was designated from topotypic specimens to prevent further confusion and misidentification.

Key words: Aedeagus, calling song, neotype, taxonomy, vesica.

INTRODUCTION

Euterpnosia Matsumura, a genus mainly distributed in the Oriental Region, contains 19 species (Chou *et al*., 1997; Duffels and van der Laan, 1985; Lee and Hayashi, 2003b). Among them, 12 endemic species occur in Taiwan, including two newly described species, namely *E. elongata* Lee and *E. laii* Lee (Lee and Hayashi, 2003b). Kato (1925, 1926, 1927a, 1927b, 1930, 1933) described eight *Euterpnosia* species from Taiwan. Since the type specimens of Kato's species are not available (Lee and Hayashi, 2003b) and no information of male genitalia is given by his works, it is questionable to identify some species merely basing on the limited information from his descriptions and illustrations.

E. varicolor Kato is named after its variable coloration. In the original description of *E. varicolor*, Kato (1926) wrote "the wart-like process of third abdominal segment very large and distinct". The distinct abdominal projections (actually on 4th tergum) and infuscations of forewing have been adopted as main diagnoses for *E. varicolor* by Lee and Hayashi (2003b). However, after examining *E. varicolor* from the type locality and the two specimens illustrated as *E. varicolor* by Lee and Hayashi (2003b, Figs. 3, 4), I found that those two specimens in their figures should belong to a new species, different from *E. varicolor* primarily in the male genitalia, the venation of forewing, the calling song, and the altitude of habitat. In order to eliminate further confusion, I herein redescribe *E. varicolor* and describe that new species and another allied new species from Coastal Range, Eastern Taiwan.

Morphology of male abdomen can be used to identify *Euterpnosia* species (Hayashi, 1974; Lee and Hayashi, 2003b). Thus I measure four variables of male abdomen to discover possible significant differences. The apical part of aedeagus has been proven to be informative and critical in taxonomy and systematics of the subtribe Cosmopsaltriina (Duffels and Turner, 2002) and the genus *Cryptotympana* (Hayashi, 1987) in Cicadidae but it has never been used for taxonomy of *Euterpnosia*. For exploring more characters to separate these three closely related species, I examine the apical part of aedeagus of each species. In addition, calling songs of these three species are very different from each other and can be used to distinguish them. Thus I analyze and characterize the calling song of each species in time and frequency domains. In conclusion, *E. varicolor* and the two new species are mainly

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different in male genitalia, especially the membranous vesica and sclerotized projections on the apical part of aedeagus, and male calling songs.

MATERIALS AND METHODS

Adults, especially singing males, were collected by netting at habitats where male choruses occurred. Alive cicadas were placed individually into glassine envelopes until they were killed by cyanide and prepared as specimens. Topotypic specimens of *E. varicolor* were collected along the road between Pailing (1300 m in alt.) and Mt. Chienchingshan (1880 m in alt.) in the area of Taipingshan, Ilan, in July 2004 and July 2005, the same season when Kato collected his types in that area (Kato, 1926). These topotypic specimens along with the original description and illustrations from Kato's publications (Kato, 1926, 1932, 1933) were adopted as fundamental references for identification and redescription of *E. varicolor*.

Type specimens of the two new species are deposited in the National Museum of Natural Science (NMNS), Taichung, Taiwan, and in my private collections (JHCC). The type specimen of *E. chinensis* Kato was examined from Institute of Zoology, Chinese Academy of Sciences (IZCAS), Beijing, China. Additional specimens were examined from Chen-Hsiang Chen's private collection (CHCC).

Measurement. Wing-spread specimens were photographed in dorsal aspect by a digital camera (Nikon E8700). The camera was zoomed to 23.7 mm in focal length, equal to 93 mm in 35 mm single-lens reflex camera. Images of specimens were measured on a personal computer in pixel unit by the software Adobe Photoshop. For each image, all measurements in pixel unit were converted to data in millimeter (mm) according to the ratio of pixel distance to actual distance. Measurements on males (Fig. 1) include body length, head and thorax length, abdomen length, head width, thorax width (mesonotum width), 3rd and 5th abdominal tergum width, abdominal projection width, and left forewing length (from the apex of forewing to the base of costal vein).

Genitalia examination. Dried or glycerin preserved male genitalia were examined and drawn by a dissecting microscope (Leica MZ125). Male pygofers were removed from fresh specimens and fixed immediately in 4 % glutaraldehyde with 0.1 M phosphate buffer, pH 7.2, for one day. Then the samples were rinsed in 0.1 M phosphate buffer before they were dehydrated by transferring them through increasing concentrations of ethanol up to absolute ethanol. Aedeagus were separated from these samples, transferred into xylene, and embedded in Entellan (Merck, Germany) on slides for light microscopy observation and photography. Some aedeagus of these samples were transferred into 100 % acetone, critical point dried in carbon dioxide, mounted on aluminum stubs with copper tape, and coated with Pt-Pb alloy for scanning electron microscope observation and photography.

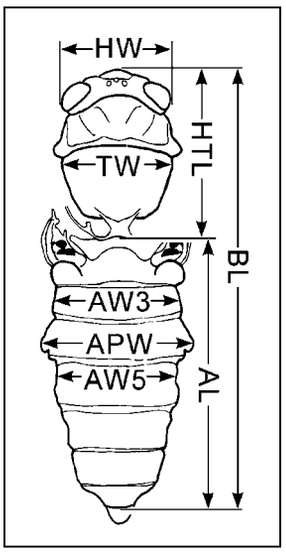

Fig. 1. Measurements of *Euterpnosia* males. AL, abdomen length; APW, abdominal projection width; AW3, third abdominal tergum width; AW5, fifth abdominal tergum width; BL, body length; HTL, head and thorax length; HW, head width; TW, thorax width.

Sound recording and analysis. Calling songs of individual males were recorded at a distance of 0.5-5 m before the males were collected as voucher specimens at the type locality of each species. Recordings were carried out by a condenser microphone (Sennheiser MKH 70, with a frequency response range of 50-20,000 kHz) connected to a digital recorder (Marantz PMD670, at a sampling frequency of 48 kHz). Acoustic signals were saved as uncompressed audio files (16 bits PCM) and analyzed by the software Avisoft-SASLab Pro (Specht, 2005), following the method described by Pinto-Juma *et al.* (2005). For the recording of each male, a segment of calling sequence, at least 30 seconds, was analyzed to calculate acoustic variables including number of frequency band modulated phrase (FBM phrase) per minute, number of echeme per second (echeme rate), echeme duration, peak frequency, and mean frequency. All recordings were stored with my private collections (JHCC). The calling song of the holotype of *E. alpina* was recorded on

a compact disk and deposited along with the holotype at NMNS.

Statistics. Since all phenetic and acoustic variables were normally distributed (Kolmogorov-Smirnov test, $p > 0.05$), the difference between variables of *E. varicolor* and *E. alpina* were tested by *t*-test. Variables of *E. madawdawensis* were not tested due to insufficient number of specimens.

Terminology. Morphological terminology follows Snodgrass (1935) and Duffels (1983) for general morphology, and Hayashi (1987) for wing venation and male genitalia. Acoustic terminology follows Sueur (2002) and Gogala (1995).

TAXONOMY

Euterpnosia varicolor Kato

(Table 1; Figs. 2, 5A-B, 6A-B, 7A-B, 8A-D, 9A-D, 10A, D, 11, 14)

Euterpnosia varicolor Kato, 1926: 174, pl. 3, figs. 3a, 3b; Kato, 1927a: 33; Kato, 1930: 53, 66; Kato, 1932: 291, pl. 19, fig. 8; Kato, 1933: pl. 30; Kato, 1938: 12; Kato, 1956: 116, 134, 187, 271; Duffels and van der Laan, 1985: 104; Chou *et al.*, 1997: 203.

Euterpnosia elongata Lee, Lee and Hayashi, 2003b: 367, figs. 6, 7, 8. **(syn. nov.)**

Diagnosis: *E. varicolor* can be distinguished from other *Euterpnosia* species by the combination of following characters: The projection on each lateral side of 4th abdominal tergum of male large and distinct (Fig. 2). Forewings spotted with infuscations on cross veins R_3-R_{4+5} (1st), R_{4+5}-M_1 (2nd), M_2-M_3 (3rd), and M_4-CuA_1 (4th), and on the apical part of veins R_{4+5}, M_1, M_2, M_3, M_4, CuA_1, and CuA_2 (infuscations on R_{4+5}, M_1, M_2, M_3, CuA_2, and 4th cross vein sometimes indistinct or absent). The segment of 1M after cross vein R-1M longer than M_2 (here the length of M_2 only includes the segment after the intersection of 3rd cross vein) on forewing (with two exceptions in thirty specimens examined) (Fig. 2A). The uncus lobe of pygofer narrowed at base (Figs. 7A-B, 8A-D). The ventral lobe of pygofer does not bear subapical projection on inner side (Figs. 7A-B, 9A-D). Kato (1940) once described another similar but larger species, *E. chinensis*, from China. The male operculum of *E. chinensis* is much shorter and more oblique (Fig. 6G). Besides, infuscations on forewing are present only on 1st and 2nd cross veins in the type specimen of *E. chinensis*.

Description: Male (Fig. 2): Head width same to mesonotum width; vertex greenish or olivaceous, a black spot on ocellar area and some irregular black marks between lateral ocelli and eyes; ocelli pink or red, sometimes yellow or greenish; postclypeus slightly protruding anteriorly, with a greenish triangular spot in front of central ocellus in dorsal view, and a wide longitudinal black fascia situated centrally in ventral view; gena pale green or pale yellow, with a black mark or oblong patch between antennal socket and eye; lorum black; anteclypeus yellow or pale greenish, with black marks which are various in shape, sometimes almost entirely black; rostrum pale greenish with black distal part, extending to coxa of hind leg.

Thorax various in coloration, sometimes clothed with sparse golden pile. Pronotum greenish to olivaceous, with longitudinal black fasciae on both sides of greenish central fascia, and with black fasciae along oblique fissures and ambient fissure; these fasciae sometimes much extended and fused together rendering inner area almost entirely black except central fascia; pronotum collar greenish with two black spots on each posterolateral lobe. Mesonotum greenish to olivaceous (often tinged with brown on anterior part), with a black middle fascia, a J-shaped black mark on inner area of each longitudinal fissure, an oblong black mark on each sublateral area, and an oval black spot in front of each side of cruciform elevation (Fig. 2A); these fasciae and marks often extended and fused together, rendering mesonotum more black (Fig. 2B), sometimes almost entirely black except a pair of paramedian greenish J-shaped patches and greenish fasciae on lateral edges (Fig. 2C); cruciform elevation greenish, often with a median black line and a black base. Operculum various in shape and size, pale greenish, pale yellow, or pale brownish, with black edge and black inner base, sometimes entirely blackened on base area; the gap between apex of operculum and posterior ridge of 2nd abdominal sternum wide; anterolateral edge usually with a rounded corner (Fig. 6A-B) (more obvious in dorsal view), the corner sometimes less obvious; posterolateral edge straight or slight curved, oblique inwards. Wings hyaline with fuscous or black veins; forewing slightly tinged with yellow and spotted with infuscations on 1st, 2nd, 3rd, and 4th cross veins, on apical part of veins R_{4+5}, M_1, M_2, M_3, M_4, CuA_1, and CuA_2, on distal angle of clavus, and on distal corner of basal cell; infuscations on R_{4+5}, M_1, M_2, M_3, CuA_2, 4th

cross veins, and distal angle of clavus sometimes indistinct or absent.

Abdomen brownish, clothed with sparse silver pile; dorsum of abdomen with paired oblong spots on 2nd, 3rd, and 4th terga (paired spots sometimes connected transversely), transverse broad fasciae on posterior half of 5th and 6th terga, transverse narrow fasciae running along anterior edge of 3rd, 4th and 5th terga, and an irregular spot on each sublateral area of 3rd, 4th and 5th terga, these spots and fasciae fuscous or black; sublateral area of 2nd, 3rd, 4th and 5th terga usually pale greenish; tymbal cover slightly everted, pilose, greenish, sometimes entirely black, with black edge; projection on each lateral side of 4th tergum large, with black tip and a distinct notch; posterior half of 5th tergum projecting laterally; 7th tergum fuscous, sometimes entirely black; 8th tergum densely covered with white wax, often with one pair of small black spots. Venter of abdomen brownish, slightly translucent; sterna covered with erect hairs; sterna also clothed with sparse white wax, especially on 2nd sternum and along lateral edge of each sternum (Fig. 5A).

Male genitalia (Fig. 7A-B): Pygofer oval, widened centrally, fuscous laterally; uncus lobe various in shape and coloration (Fig. 8A-D), with narrowed base, triangular apex, and sometimes a longitudinal obscure fascia situated centrally (Figs. 7A, 8B); ventral lobe also various in shape (Figs. 7A-B, 9A-D), with straight or sinuate inner edge; apical part of aedeagus (Fig. 10A, D) with a longitudinal split opening dorsally, and bearing one apical and one subapical sclerotized projections; both projections toothlike, flat, with slightly indented edge; apical projection slightly deflected to the right side of aedeagus; membranous vesica hyaline, extending dorsally from the middle of the split.

Female also various in coloration, but usually more green than male; black fasciae on pronotum and mesonotum well separated; inner area of pronotum and dorsum of mesonotum never entirely black as those in some males; lateral area of 2nd, 3rd, and 4th terga covered with silver hairs; 8th tergum often covered with white wax, but white wax sometimes indistinct or absent.

Calling song: Composed by alternate FBM phrases and buzzing phrases without clearly defined echemes (Fig. 11). FBM and buzzing phrases are approximately the same in length but different in frequency domain. During FBM phrases, some energy is shifted into the lower frequency bands with peaks at about 2.6 and 5.2 kHz (Fig. 11A). This feature is not frequency modulation because the pitch of frequency bands does not change. For other acoustic variables, see Table 1. Acoustically, the calling song heard in the type locality is just like "Mee-n! Mee-n! Mee-n!", exactly corresponding to that described by Kato (1926, 1956).

Measurement: 17 ♂, 7 ♀. Body length: ♂, 25.3-28.0 mm (pygofer and hypandrium excluded); ♀ , 20.6-24.4 mm (ovipositor included). See Table 1 for details.

Material examined: All from Taiwan. 1 ♂, Ilan Hsien (Co.), Tatung Hsiang, en route from Pailing to Taipingshan, alt. 1400-1600 m, 5 VII 2005, JH Chen leg., NMNS 4929-57; 10 ♂, same data, JHCC 0991-1000; 1 ♂, same locality and collector, 13 VII 2004, JHCC 0799; 1 ♀, same locality, at light, 4 VII 2000, SY Wu leg., JHCC 0225; 1 ♂, Ilan Hsien, Tatung Hsiang, Tuleng, by light trap, 28 VI 2001, SY Wu leg., JHCC 0244; 1 ♂, 1 ♀, Ilan Hsien, Tatung Hsiang, Ssuyuan-ukou, 10 VI 2005, IF Lee leg., JHCC 1005-1006; 1 ♀, same locality, 4 VI 2003, SY Wu leg., JHCC 1007; 2 ♂, Taichung Hsien, Heping Hsiang, Ssuyuan, 6 VII 2005, JH Chen leg., JHCC 1001-1002; 2 ♂, 1 ♀, same locality, 18 VI 2004, CH Chen leg., CHCC; 1 ♂, Taoyuan, Shangbaling, 21-23 VI 1989, CS Lin leg., NMNS 732-527 (holotype of *Euterpnosia elongata*); 4 ♂, 4 ♀, Taoyuan Hsien, Fuhsing Hsiang, Mt. Chatienshan, alt. 1750 m, by light trap, 19 VI 2004, WI Chou leg., JHCC 1008-1015.

Distribution: Endemic to the mountain area of northern Taiwan.

Biology: According to my observation in the area around Taipingshan, *E. varicolor* inhabit the broad-leaved forest, ranging in altitude from 1300 to 1800 m. The highest record is at Ssuyuan, Taichung Co., 1950 m in altitude. Adults occur from June to August (Kato, 1926, 1927a, 1932; J.H. Chen, pers. obs.). The peak of occurrence is probably around the first week of July in the Taipingshan population. Males chorus most actively between 07:00 and 11:00, just before the sunshine is diminished by cloud and mist. A short period of dusk chorus occurs after 19:00. Adults can be attracted to mercury-vapor lights.

***Euterpnosia alpina* Chen, sp. nov.**

(Table 1; Figs. 3, 5C, 6C-D, 7C, 8E-F, 9E-F, 10B, 12, 14)

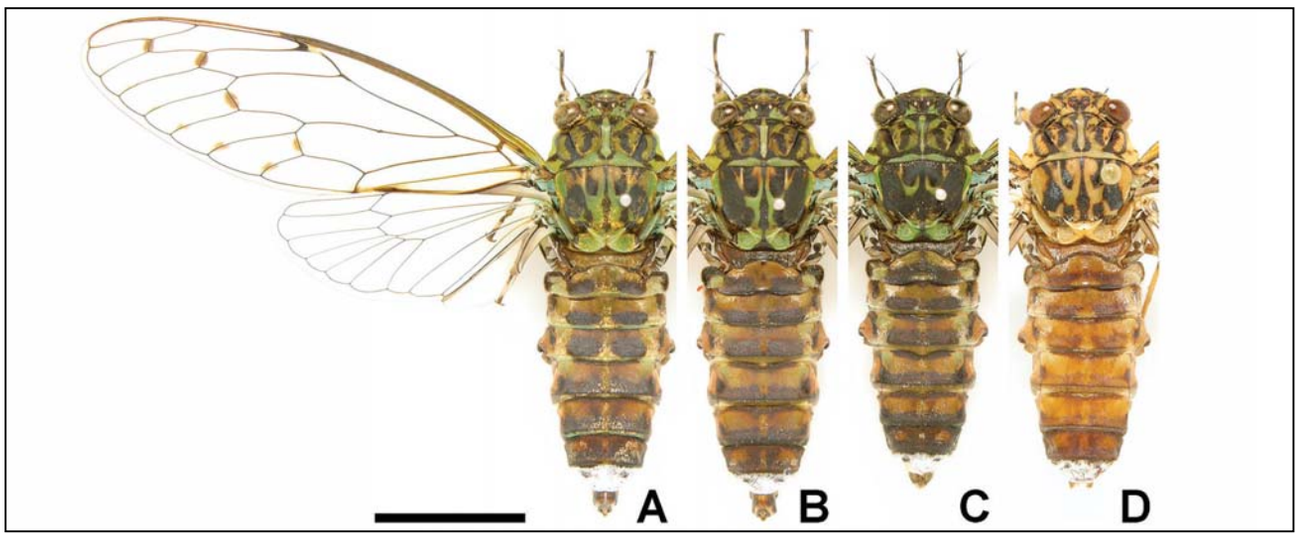

Fig. 2. *Euterpnosia varicolor* males in dorsal view. (A) neotype, NMNS 4929-57; (A-C) from type locality, en route from Pailing to Taipingshan, Ilan Co.; (D) from Shangbaling, Taoyuan Co. (holotype of *E. elongata*, NMNS 732-527). Scale bar = 10 mm.

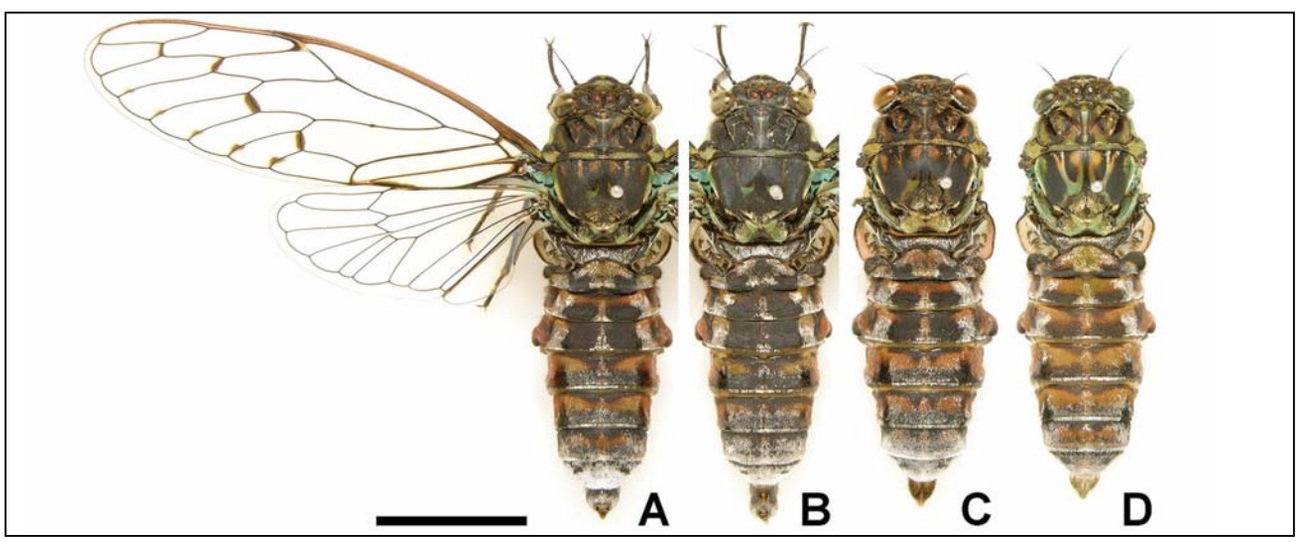

Fig. 3. *Euterpnosia alpina* males in dorsal view, showing variations of coloration and abdomen shape. (A) holotype, NMNS 4929-4; (B-D) paratypes; (B) from Kuanyuan, Hualien Co.; (C, D) from type locality, Fushoushan Farm, Taichung Co. Scale bar = 10 mm.

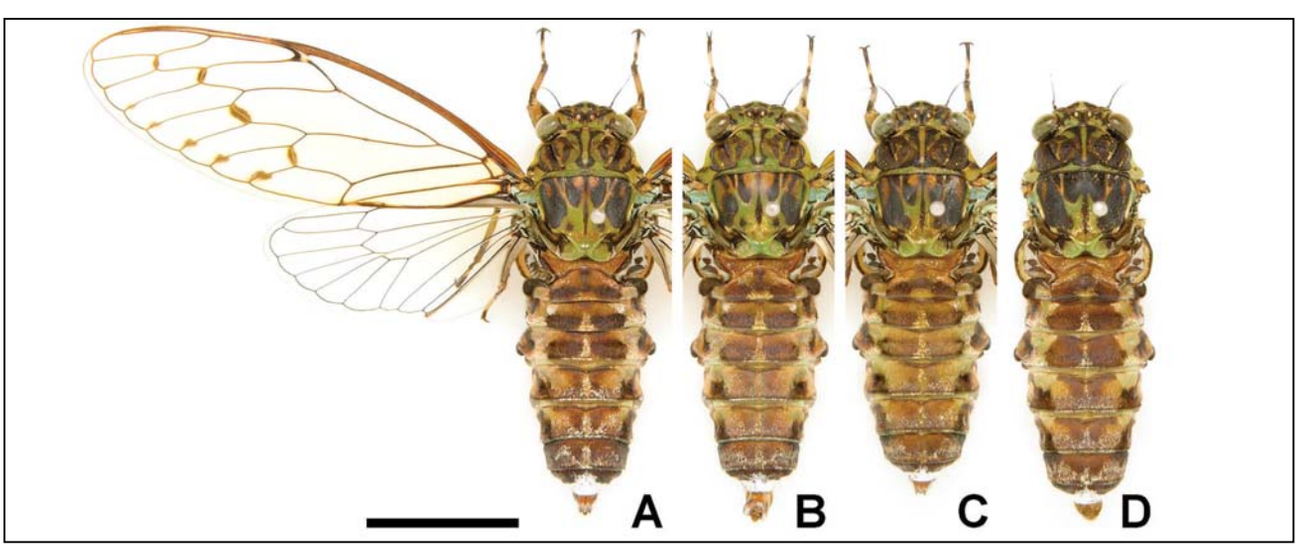

Fig. 4. *Euterpnosia madawdawensis* males in dorsal view, showing variations of coloration and abdomen shape. (A) holotype, NMNS 4929-1; (B-D) paratypes; (A-D) from type locality, Mt. Hsinkangshan, Hualien Co. Scale bar = 10 mm.

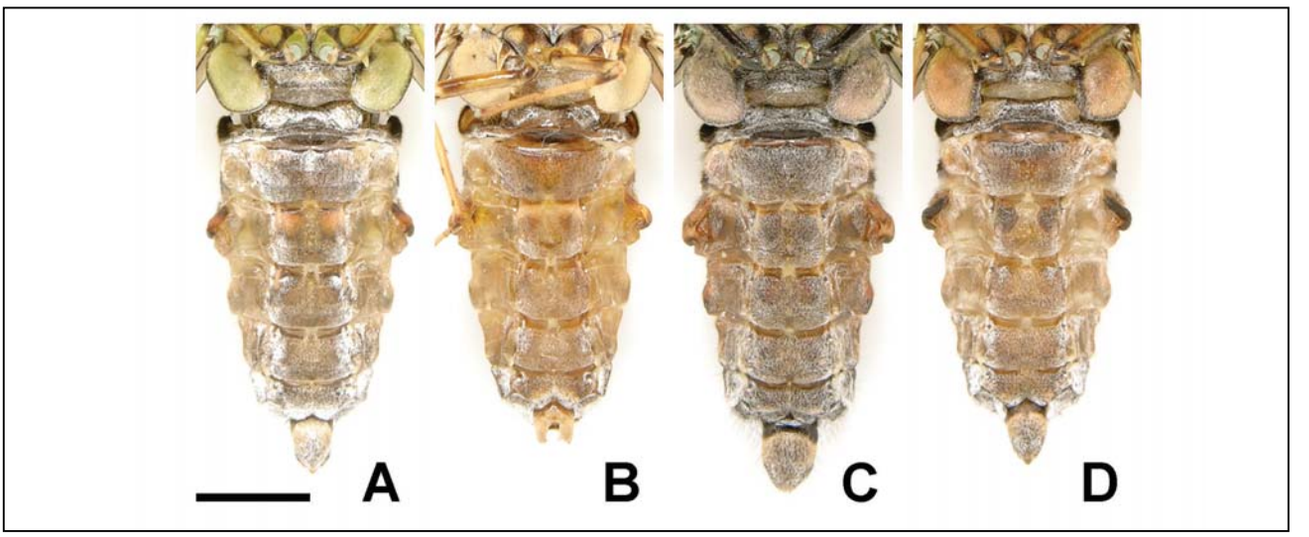

Fig. 5. Male abdomens of *Euterpnosia* species in ventral view. (A) *E. varicolor*, neotype; (B) *E. varicolor*, holotype of *E. elongata*; (C) *E. alpina*, holotype; (D) *E. madawdawensis*, holotype. Scale bar = 5 mm.

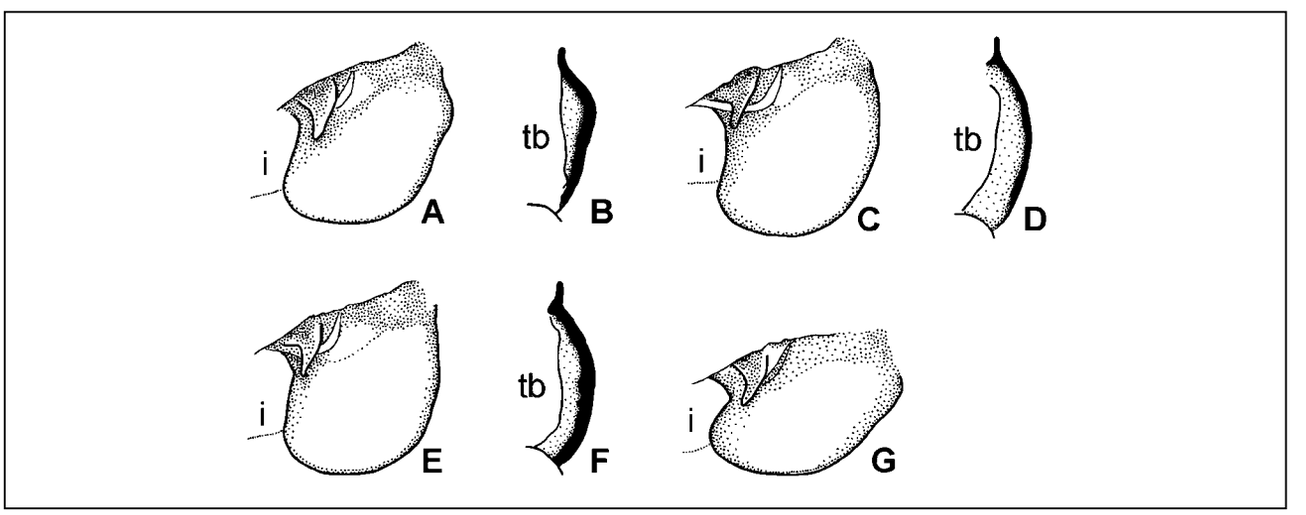

Fig. 6. Male opercula of *Euterpnosia* species. (A, B) *E. varicolor* from type locality; (C, D) *E. alpina*, paratype; (E, F) *E. madawdawensis*, paratype; (G) *E. chinensis*, type specimen; (A, C, E, G) in ventrolateral view; (B, D, F) lateral edge of opercula in dorsal view; (i) first abdominal sternum; (tb) tymbal.

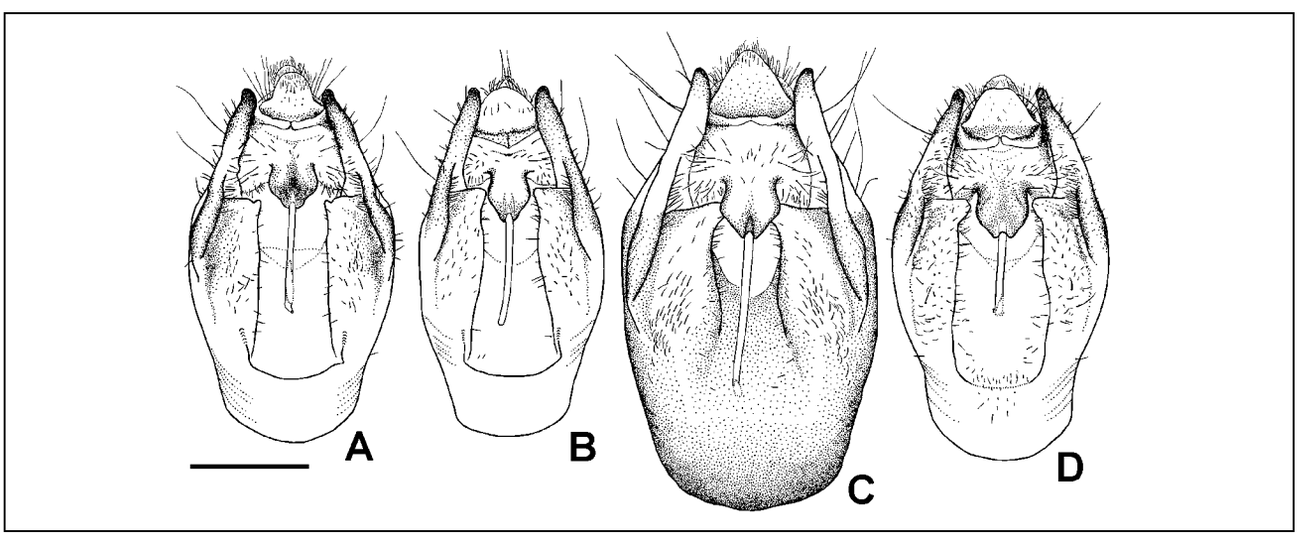

Fig. 7. Male genitalia of *Euterpnosia* species in ventral view. (A) *E. varicolor* from type locality, JHCC 0799; (B) *E. elongata*, holotype, NMNS 732-527; (C) *E. alpina*, paratype, NMNS 4929-43; (D) *E. madawdawensis*, paratype, JHCC 0781. Scale bar = 1 mm.

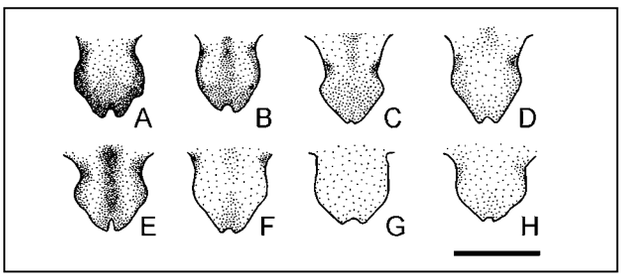

Fig. 8. Variations in shape and coloration of uncus lobe in *Euterpnosia* male genitalia. (A-D) *E. varicolor* from type locality; (E, F) *E. alpina*, paratypes; (G, H) *E. madawdawensis*, paratypes. Scale bar = 0.5 mm.

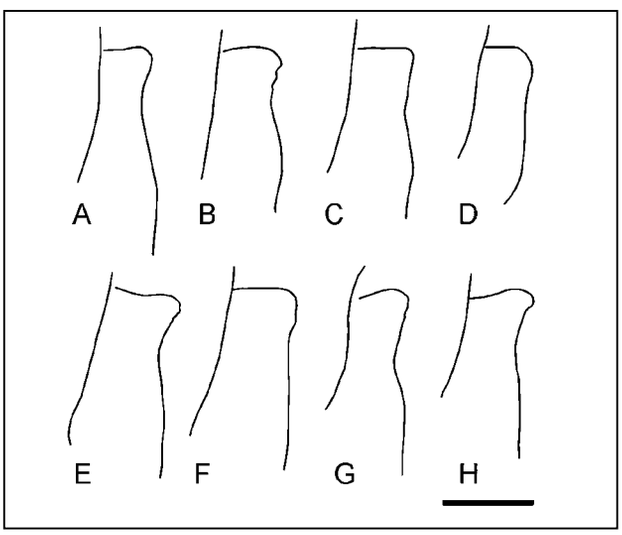

Fig. 9. Variations in shape of ventral lobe in *Euterpnosia* male genitalia. (A-D) *E. varicolor*; (E, F) *E. alpina*, paratypes; (G, H) *E. madawdawensis*, paratypes. Scale bar = 0.5 mm.

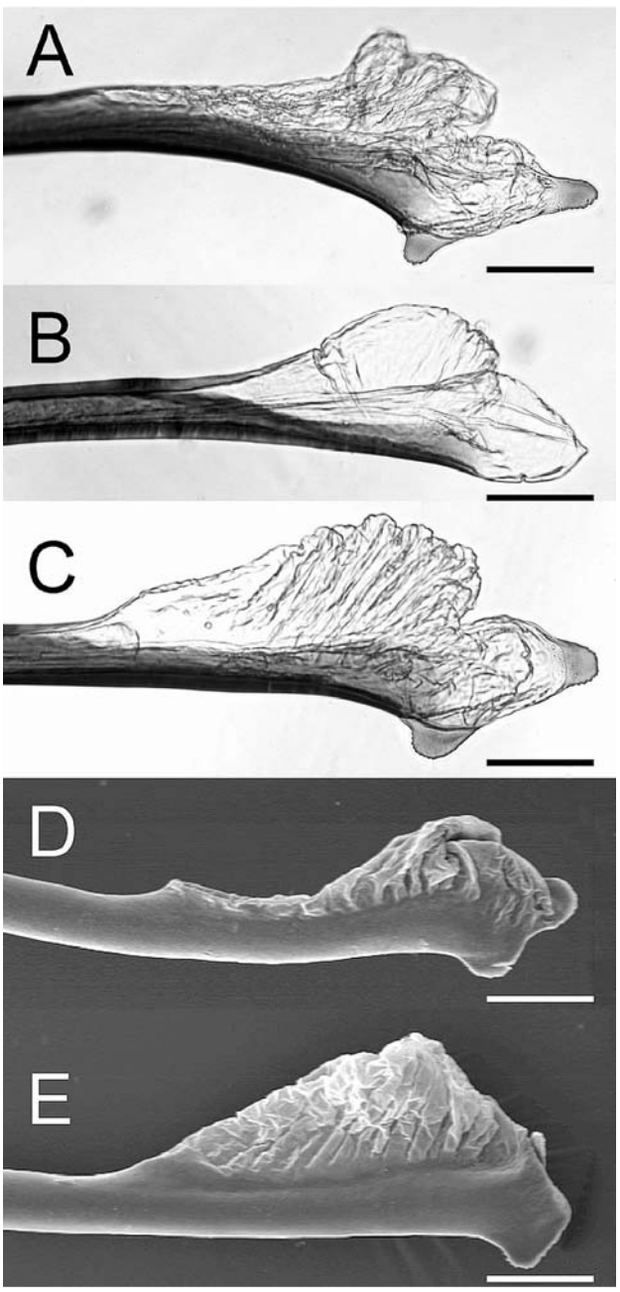

Fig. 10. Apical parts of aedeagus of *Euterpnosia species* in lateral view, left side. (A, D) *E. varicolor* from type locality; (B) *E. alpina*, paratype; (C, E) *E. madawdawensis*, paratypes; (A-C) by light microscopy; (D-E) by scanning electron microscopy. Scale bar = 100 μm.

Euterpnosia varicolor, Lee and Hayashi, 2003b: 364, figs. 3, 4, 5. (misidentification)

Diagnosis: *E. alpina* is similar with *E. varicolor* in appearance and coloration but *E. alpina* differs clearly from *E. varicolor* in following characters: The segment of 1M after cross vein R-1M shorter than M_2 (the length of M_2 only includes the segment after the intersection of 3rd cross vein) on forewing (Fig. 3A). Wing veins darker and thicker (Fig. 3A). The projection on each lateral side of male 4th abdominal tergum more protruding and more distinct (Figs. 3, 5C, 14). The pygofer distinctly larger (ca. 4 mm in length) and more protruding laterally (Fig. 7C). The apical part of aedeagus does not bear sclerotized projection (Fig. 10B). Other statistically significant, but not so obvious differences from *E. varicolor* include longer head and thorax length, narrower third abdominal tergum width, wider abdominal projection width, and shorter forewing (Table 1). In any case, the absence of sclerotized projections on the apical part of aedeagus is the most reliable character to distinguish *E. alpina* from *E. varicolor*. In addition, it is also reliable to distinguish female *E. alpina* from female *E. varicolor* by the shorter segment of 1M after cross vein R-1M.

Table 1. Phenetic and acoustic variables of male *Euterpnosia varicolor*, *E. alpina*, and *E. madawdawensis*. Asterisks indicate significant difference from the variable of *E. varicolor* (*t*-test). Variables of *E. madawdawensis* were not tested due to insufficient number of specimens. Single asterisk, $p < 0.05$; double asterisks, $p < 0.01$; triple asterisks, $p < 0.001$; SD, standard deviation; *n*, number of specimens measured; NA, not available; FBMP, frequency band modulated phrase.

Variables	*E. varicolor*		*E. alpina*		*E. madawdawensis*	
	Neotype	Average ± SD (*n*)	Holotype	Average ± SD (*n*)	Holotype	Average ± SD (*n*)
Phenetic variables (mm)						
Body length	26.5	26.70 ± 0.79 (17)	27.3	26.93 ± 0.87 (14)	25.7	25.63 ± 0.53 (4)
Head and thorax length	10.8	10.47 ± 0.39 (17)	11.2	10.78 ± 0.32 (14)*	10.2	10.03 ± 0.11 (4)
Abdomen length	15.7	16.23 ± 0.55 (17)	16.2	16.16 ± 0.66 (14)	15.6	15.60 ± 0.55 (4)
Head width	7.1	6.82 ± 0.22 (17)	6.8	6.90 ± 0.14 (14)	6.6	6.66 ± 0.11 (4)
Thorax width	6.9	6.93 ± 0.24 (17)	6.7	6.92 ± 0.25 (14)	6.7	6.68 ± 0.14 (4)
3rd abdominal tergum width	7.9	7.74 ± 0.23 (17)	7.3	7.48 ± 0.26 (14)**	7.9	7.79 ± 0.08 (4)
Abdominal projection width	9.2	9.02 ± 0.26 (17)	9.4	9.30 ± 0.26 (14)**	9.2	9.17 ± 0.07 (4)
5th abdominal tergum width	7.1	7.03 ± 0.24 (17)	7.2	7.20 ± 0.29 (14)	7.1	7.29 ± 1.34 (4)
Forewing length	32.2	32.19 ± 0.81 (17)	31.8	31.47 ± 0.65 (14)**	30.5	31.01 ± 0.90 (4)
Acoustic variables						
No. of FBMP per min	NA	86.5 ± 10.1 (13)		FBMP absent	NA	9.68 ± 3.75 (2)
Echeme rate (per s)		Echeme absent	12.98	11.44 ± 1.28 (7)		Echeme absent
Echeme duration (ms)		Echeme absent	53.19	63.14 ± 10.58 (7)		Echeme absent
Peak frequency (Hz)	NA	13219 ± 552 (11)	10610	11046 ± 477 (8)***	NA	16277 ± 37 (2)
Mean frequency (Hz)	NA	13014 ± 548 (11)	10626	11114 ± 296 (8)***	NA	12656 ± 2121 (2)

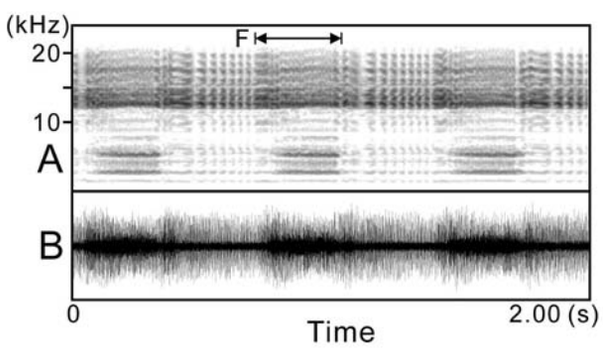

Fig. 11. Calling song of *Euterpnosia varicolor* from type locality, showing three successive sequences. (A) spectrogram; (B) oscillogram; (F) one period of frequency band modulated phrase.

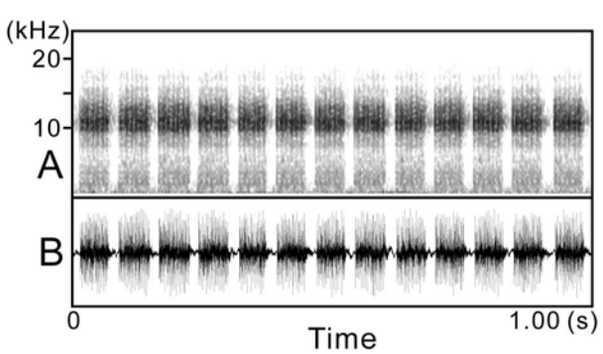

Fig. 12. Calling song of *Euterpnosia alpina*, holotype, NMNS 4929-4, showing thirteen successive echemes. (A) spectrogram; (B) oscillogram.

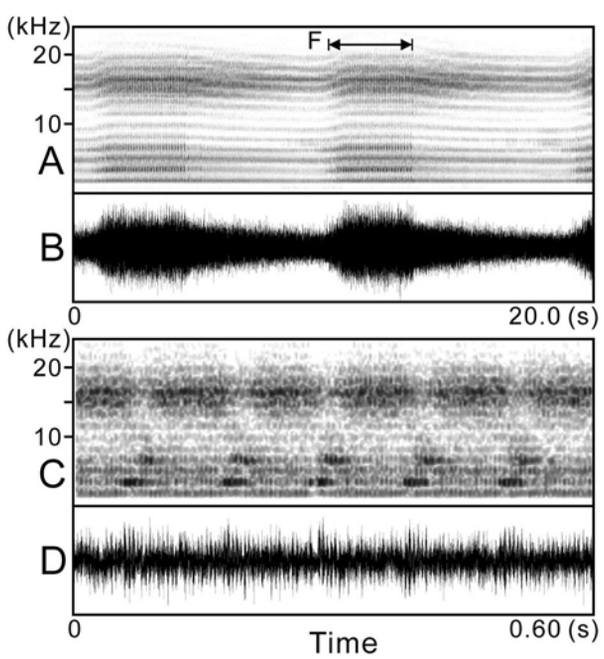

Fig. 13. Calling song of *Euterpnosia madawdawensis* from type locality. (A, B) spectrogram and oscillogram of two successive sequences; (C, D) spectrogram and oscillogram of a portion of frequency band modulated phrase, showing five times of frequency shift; (F) one period of frequency band modulated phrase.

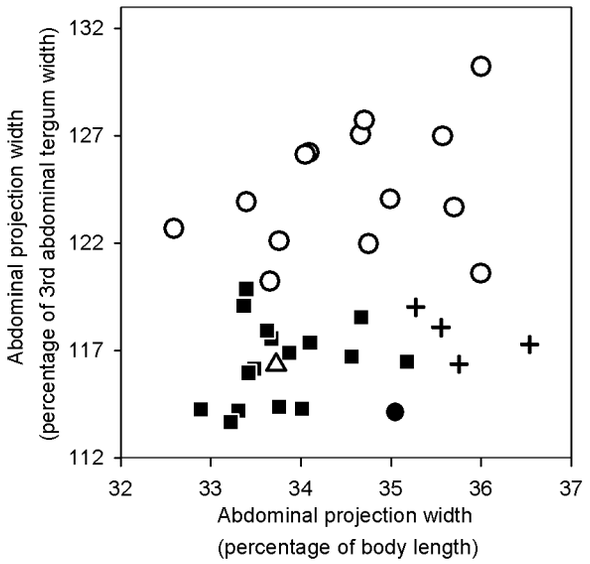

Fig. 14. Ratio of abdominal projection width (width of 4th abdominal tergum) in male *Euterpnosia* specimens. Square, *E. varicolor*; open circle, *E. alpina*; cross, *E. madawdawensis*; triangle, holotype of *E. elongata*; closed circle, type specimen of *E. chinensis*.

Description: Male (Fig. 3): Head width same to mesonotum width; vertex usually black, sometimes with few greenish areas; ocelli red or orange; postclypeus slightly protruding anteriorly, with an olivaceous triangular spot in front of central ocellus in dorsal view, and a wide longitudinal black fascia situated centrally in ventral view; gena black, with a small pale yellow patch next to lorum and densely covered with white hairs; lorum black and pilose; anteclypeus black, sometimes bordered anteriorly with brown or yellow edge; rostrum pale olivaceous with black distal part, usually extending to coxa of hind leg.

Thorax various in coloration, sometimes clothed with sparse silver pile. Coloration of pronotum as that of *E. varicolor*, but black fasciae usually more extended rendering inner area much fuscous or even entirely black with a very narrow and indistinct dull central fascia. Mesonotum usually black with very few greenish or brown area (Fig. 3A-C), rarely greenish with black fasciae (Fig. 3D) as those in *E. varicolor*; lateral edges of mesonotum always greenish; cruciform elevation greenish, often with a black or fuscous base. Operculum various in shape and coloration, fuscous, brownish, or pale yellow, sometimes pink, usually pilose, with black edge and black inner base, the gap between apex of operculum and posterior ridge of 2nd abdominal sternum small or absent in ventral view (Fig. 5C); lateral edge rounded (Figs. 3C, 6C-D), sometimes angled as that in *E. varicolor* (Fig. 3D). Wings hyaline with black veins; forewing usually not tinged with yellow; forewing spotted with infuscations as those in *E. varicolor*; the segment of 1M after cross vein R-1M distinctly shorter than the segment of M_2 after intersection of 3rd cross vein on forewing.

Coloration of abdomen similar to that of *E. varicolor* but much darker and more pilose; paired black spots on 2nd, 3rd, and 4th terga larger, the last pair often extending anteriorly to front edge of 4th tergum; first tergum and sublateral area of 2nd, 3rd, and 4th terga always clearly clothed with silver pile; tymbal cover slightly everted, pilose, usually entirely black; anterior part of 3rd tergum clearly narrow than posterior part; projection on each lateral side of 4th tergum very large, with rounded and fuscous tip and a distinct notch; posterior half of 5th tergum projecting laterally (with one exception in fourteen males); 7th and 8th terga as those in *E. varicolor*. Venter of abdomen (Fig. 5C) similar to that of *E. varicolor*; projection on each lateral side of 4th tergum with much thicker ridge in ventral view; 8th sternum (hypandrium) distinctly larger than that of *E. varicolor*.

Male genitalia (Fig. 7C): Pygofer similar to that of *E. varicolor*, but much larger, more fuscous, and protruding more on lateral side; uncus lobe various in shape and coloration (Fig. 8E-F), with narrowed base and triangular apex, and usually with a longitudinal dark fascia situated centrally (Fig. 8E); ventral lobe also various in shape (Figs. 7C, 9E-F), with less or more sinuate inner edge; apical part of aedeagus (Fig. 10B) with a hyaline, flat, leaf-like apex; membranous vesica hyaline, saccate, extending dorsally from the split of aedeagus (the vesica partially or largely shrinks in dried specimens).

Female also various in coloration, very similar to female of *E. varicolor*, but 1M (after cross vein R-1M) obviously shorter than M_2 on forewing; ovipositor thicker than that of *E. varicolor*.

Calling song: Composed by quickly repeated short echemes (Table 1, Fig. 12). The calling song of *E. alpina* is very different from that of *E. varicolor* in the presence of clearly defined echemes, the lack of FBM phrase, and the significantly lower pitch (Table 1, see peak and mean frequency). Lee and Hayashi (2003b, p. 366) also described the calling song of *E. alpina*.

Measurement: 14 ♂, 39 ♀. Body length: ♂, 25.6-28.3 mm (pygofer and hypandrium excluded); ♀ , 21.4-25.7 mm (ovipositor included). See Table 1 for details.

Type series: All from Taiwan. Holotype: 1 ♂, Taichung Hsien (Co.), Heping Hsiang, Fushoushan Farm, 16 V 2005, JH Chen leg., NMNS 4929-4 (ex JHCC 0899). Paratypes: 3 ♂, same data as for holotype, NMNS 4929-43~4929-45 (ex JHCC 0900-0902); 2 ♂, same locality and collector, 15 V 2005, JHCC 0889, 0890; 8 ♀, same data, NMNS 4929-35~4929-42 (ex JHCC 0891-0898); 8 exuviae, same data, NMNS 4929-46~4929-53 (ex JHCC 0903-0910); 2 ♀ , Taichung Hsien, Heping Hsiang, Shengkuang, by light trap, 19:00, 11 V 2002, SP Wu leg., NMNS 4929-55~4929-56 (ex JHCC 0461-0462); 1 ♂, 2 ♀, Hualien Hsien, Hsiulin Hsiang, Kuanyuan, alt. 2350 m, at light, V 2005, collector unknown, JHCC 0856, 0863, 0864; 6 ♂, 24 ♀, same data, NMNS 4929-5~4929-34; 1 ♀, same locality, 28 V 1995, WI Chou leg., NMNS (uncatalogued); 1 ♀, Hualien Co., Piluchi For. Res. Sta., 2100 m, 24 V 1997, C W. & LB O'Brien leg., NMNS 4299-7; 1 ♂, Nantou, Piluchi, 6 V 1997, MM Yang leg., NMNS 2708-715; 1 ♀, same locality and collector, 15-30 V 1997, NMNS 2708-475; 1 ♀, Nantou, Chunyang, 28 IV 1995, ML Chan and WT Yang leg., NMNS 2070-1.

Distribution: Known only from the mountain area in Central Taiwan.

Etymology: The Latin *alpina* refers the alpine region where this species inhabit (Lat. Alpinus, ~a, ~um, adj: of, or belonging to, the Alps, Alpine).

Biology: *E. alpina* inhabit the coniferous forest, ranging in altitude from 2000 to 2400 m. Adults occur mainly from May to June. My observation in the Fushoushan Farm showed that most exuviae were found on the trunks of *Pinus taiwanensis* (n = 36), and few on *Cryptomeria japonica* (n = 4). Males usually call solo or chorus with few other males on high twigs of *P. taiwanensis* under the sunshine. Calling activities last all day if the sunshine is present. According to my night observation made on 15 May, 2005, eclosion of nymphs occurred between 20:00 and 00:00 at low temperature (12 ℃). Adults can be attracted to mercury-vapor lights.

***Euterpnosia madawdawensis* Chen, sp. nov.**

(Table 1; Figs. 4, 5D, 6E-F, 7D, 8G-H, 9G-H, 10C, E, 13, 14)

Diagnosis: *E. madawdawensis* is very similar with *E. varicolor* in appearance and coloration but this species differs from *E. varicolor* in following characters: The abdominal projection wider (35.3-36.5 percent of body length) (Fig. 14). The tinge of forewing more obvious. The outer edge of male operculum rounded (Fig. 6E-F), not angled as that appears in *E. varicolor*. The uncus lobe of pygofer not narrowed at base (Figs. 7D, 8G-H). The membranous vesica of aedeagus more expansive, flag-like, extending abruptly from the proximal start of the split on the apical part of aedeagus (Fig. 10C, E).

Description: Male (Fig. 4): Head width same to mesonotum width; vertex, postclypeus, gena, and lorum as those in *E. varicolor*; anteclypeus yellow with a pair of black marks which are often connected centrally; rostrum pale olivaceous with black distal part, extending to coxa of hind leg.

Thorax various in coloration, sometimes clothed with sparse golden pile. Coloration of pronotum and mesonotum as that of *E. varicolor*, but anterior part of mesonotum more brownish. Operculum ochraceous or pale olivaceous, with black edge and black inner base; the gap between apex of operculum and posterior ridge of 2nd abdominal sternum very small (Fig. 5D); lateral edge rounded (Fig. 6E-F). Wings hyaline with brown veins; forewing obviously tinged with yellow and spotted with infuscations as those in *E. varicolor*.

Abdomen very similar to that of *E. varicolor*, but slightly shorter; tymbal cover slightly everted, pilose, entirely black; anterior part of 8th tergum black; posterior part of 8th tergum thickly covered with white wax but without a pair of small black spots.

Male genitalia (Fig. 7D): Pygofer similar to that of *E. varicolor* in size and shape, but lateral side of pygofer brownish on apical half and pale yellow on basal half, not so fuscous as that in *E. varicolor*; uncus lobe not narrowed at base (Figs. 7D, 8G-H); ventral lobe with straight or sinuate inner edge; apical part of ventral lobe sometimes protruding inwards (Figs. 7D, 9H); apical part of aedeagus (Fig. 10C, E) with a longitudinal split opening dorsally, and bearing one apical and one subapical sclerotized projections; both projections toothlike, flat, with slightly indented edge; apical projection deflected to the right side of aedeagus; membranous vesica hyaline, extending abruptly from the proximal start of the split, and bearing parallel folds.

Calling song: Composed by alternate FBM phrases and buzzing phrases without clearly defined echemes (Fig. 13). Both FBM and buzzing phrases are much longer than those of *E. varicolor*. At the beginning of FBM phrase, the higher frequency bands are slightly raised in pitch (Fig. 13A). During FBM phrase, energy is periodically shifted into the lower frequency bands with a peak at about 3 kHz, accompanying with attenuation in the high frequency bands around 16 kHz (Fig. 13C). The shift of frequency occurs at a rate of 8.7-9.2 times per second (n = 2). The intensity (amplitude) gradually decreases during buzzing phrase until next FBM phrase. Acoustically, the calling song of *E. madawdawensis* is like "GeGeGeGeGeGe…… gi------", similar to those of *E. olivacea, E. koshunensis, E. gina, and E. arisana* which also have repeated frequency shift during FBM phrases.

Measurement: 4 ♂. Body length: ♂, 24.9-26.2 mm (pygofer and hypandrium excluded). See Table 1 for details.

Type series: All from Taiwan. Holotype: 1 ♂, Hualien Hsien (Co.), Fuli Hsiang, Mt. Hsinkangshan, alt. 1500 m, 29 V 2004, JH Chen leg., NMNS 4929-1 (ex JHCC 0778). Paratypes: 2 ♂, same data as for holotype, NMNS 4929-2~4929-3 (ex JHCC 0779-0780); 1 ♂, same data as for holotype, JHCC 0781.

Distribution: Known only from Mt. Hsinkangshan in Coastal Range, Eastern Taiwan.

Etymology: This species is named after the old name of the type locality, Mt. Madawdawshan, which is named after a nearby village of Pangcha (Amis) Tribe (Huang and Luo, 2001).

Biology: *E. madawdawensis* are very abundant in the primary forest in the west area of Mt. Hsinkangshan, ranging in altitude from 1100 to 1600 m. Adults occur in May and June. Calling activities peak in the morning and last for the rest of the day. Adults usually perch in the forest canopy and always feign death after falling into the net.

DISCUSSION

Confirmation on topotypic specimens of E. varicolor. Although type specimens of *E. varicolor* are not available, the original description and following publications of Kato (1926, 1932, 1933) confirm that the topotypic specimens described herein are identical to *E. varicolor* in morphology, acoustics, locality, and season. For example, all male *E. varicolor* illustrated by Kato (1926, 1932, 1933) have 1M (the segment after cross vein R-1M) longer than M_2 on forewing and large abdominal projections (but not so large as those in *E. alpina*). Kato (1932) also stated that the shape of male operculum is similar to a parallelogram with rounded corners. These features are corresponding to my topotypic specimens. The original description shows Kato collected his types in Mt. Taihei (Taipingshan) near Rato (Luotung, Ilan) in July. According to my observation in the area around Taipingshan in 2004 and 2005, only two *Euterpnosia* species occur in that area in July. One is *E. viridifrons* and the other is morphologically identical to *E. varicolor*. Besides, all male *E. varicolor* I observed there produced the same calling song as that described by Kato (1926, 1956). Kato's description on the calling song of *E. varicolor* should be very reliable because he collected type specimens, probably singing males, by himself (Kato, 1926). Consequently, I believe that the specimens collected in the area of Taipingshan in July are undoubtedly belonging to *E. varicolor* and can be regarded as topotypic specimens.

It is necessary to clarify the type locality of *E. varicolor* by current place name. In Kato's times, the name "Mt. Taihei" (in Japanese) or "Taipingshan" (in Chinese) referred to the great mountain area of lumbering, but at present, "Taipingshan" specifically refers to the locality of the Taipingshan Forest Recreation Area (TFRA), 1950-2000 m in altitude. However, I did not observe any *Euterpnosia* species in the TFRA in July and August. The precise type locality is possible located along the road between Pailing (1300 m in alt.) and Mt. Chienchingshan (1880 m in alt.) because singing males of *E. varicolor* are heard only in that section.

Confusion on E. varicolor, E. elongata and E. alpina. After examining the only male specimen in the type series of *E. elongata*, i.e. the holotype, I considered that *E. elongata* should be a synonym of *E. varicolor*. First, the coloration and morphology of the holotype (Figs. 2D, 5B) is corresponding to the original description and illustrations of *E. varicolor* (Kato, 1926), and very similar to topotypic specimens of *E. varicolor* (Figs. 2A-C, 5A). Second, although Lee stated "ateral swellings on 4th abdominal segment comparatively small and triangular" as a diagnosable character for *E. elongata* (Lee and

Hayashi, 2003b), the size of the holotype's abdominal projection (Figs. 2D, 5B) is the same with those of type specimens of *E. varicolor* illustrated by Kato (1926, Figs. 3a, 3b). The abdominal projection width of the holotype is also exactly in the range of intraspecific variation of *E. varicolor* (Fig. 14). Third, the male genitalia of the holotype (Fig. 7B) does not distinctly differ from that of *E. varicolor*. Moreover, the holotype could be reasonably identified as a different species from *E. varicolor* and regarded as a new species because the previous concept of *E. varicolor* (Lee and Hayashi, 2003b) is mainly based on the misidentification of *E. alpina*.

Lee and Hayashi (2003b) redescribed *E. varicolor* but the description is mainly based on *E. alpina*. Both specimens (NMNS 2708-715 and 2070-1) they illustrated appear to be *E. alpina* because the vein 1M (after cross vein R-1M) is obviously shorter than the vein M_2 on forewing and the abdominal projection of the male is larger. After examining the male genitalia of the male they illustrated (Lee and Hayashi, 2003b, Fig. 3), I confirmed that the male is *E. alpina* because sclerotized projections are absent on the apical part of aedeagus (the aedeagus is mounted on the slide and placed with the paratype, NMNS 2708-715). Lee and Hayashi (2003b) also noticed some features belonging to *E. alpina*, such as thicker wing veins, longer M_2 on forewing, and the unique male calling song composed by quickly repeated echemes. Besides, although I were unable to examine most materials they examined in their description on *E. varicolor*, at least eight specimens identified as *E. varicolor* were collected in the altitude above 2000 m, thus likely belonging to *E. alpina*.

The inaccessibility of Kato's type specimens should contribute somewhat to the misidentification of *E. varicolor* and *E. alpina*. Unfortunaly, the type specimens of *E. varicolor* along with the Kato's private collection are lost permanently (Y. Saisho, K. Hashimoto, M. Hayashi, pers. comm.). In fact, in the recent review of Cicadidae from Taiwan, Lee and Hayashi (2003a, 2003b, 2004) could not examine any type specimen of Kato's species. A name-bearing type for *E. varicolor* should be designated to avoid further confusion. According to the original description on coloration, one greenish male of *E. varicolor* from the type locality was designated as neotype (Fig. 2A, Table 1). The neotype is deposited in the National Museum of Natural Science, Taichung, Taiwan, no. 4929-57, labeled as "[0990] Taiwan/ Ilan Hsien/ Tatung Hsiang/ en route from Paling to Taipingshan/ in alt. 1400-1600 m VII-5-2005 Jian-Hong Chen" (printed).

Relationships of Euterpnosia species. Relationships within *Euterpnosia* remain poorly understood. Male genitalia are often poorly described in the genus and few other characters can be used to recognize species-groups. *E. varicolor*, *E. alpina*, and *E. madawdawensis* probably belong to a species-groups because they share the same characters including large abdominal projections, paired large spots on 2nd, 3rd, and 4th abdominal terga, identical infuscations on forewings, and ventral lobes of pygofer bearing no subapical projection on inner edge. Subapical projections of ventral lobe are also absent in *E. viridifrons* Matsumura (Lee and Hayashi, 2003b) and *E. iwasakii* (Matsumura) (Hayashi, 1974), but abdominal projections are much smaller in both species. In contrast, subapical projections of ventral lobe are present in many other *Euterpnosia* species, including *E. hoppo* Matsumura, *E. suishana* Kato, *E. kotoshoensis* Kato, *E. olivacea* Kato, *E. gina* Kato (Lee and Hayashi, 2003b), *E. koshunensis* Kato, *E. arisana* Kato, *E. laii* Lee (pers. obs.), *E. chibensis* Matsumura (Hayashi, 1974), *E. crowfooti* (Distant) (Hayashi, 1978a), *E. madhava* (Distant) (Hayashi, 1978b), and *E. ruida* Lei & Chou (Chou *et al*., 1997). In addition, sclerotized projections on the apical part of aedeagus are present in *E. varicolor* and *E. madawdawensis* but completely absent in *E. alpina*, suggesting a more closed relationship between *E. varicolor* and *E. madawdawensis*.

Male genitalia and the apical part of aedeagus. Shapes of the uncus lobe and the ventral lobe of male pygofer are useful for species identification in *Euterpnosia* (Lee and Hayashi, 2003b) but I suggest intraspecific variations (Figs. 8, 9) should be considered. I demonstrate that the vesica and sclerotized projections on the apical part of aedeagus are more useful and reliable for identifying the three closed related species studied here. I suggest that the apical part of aedeagus should also be useful for identifying other *Euterpnosia* species.

Yang and Chang (2000) once described male genitalia of *E. iwasakii*, *E. gina*, and *E. kotoshoensis* in their dissecting study on male genitalia of Hemiptera. However, judging from the

uncus lobe and the ventral lobe of male genitalia they illustrated (Yang and Chang, 2000, Figs. 49, 53, 54), I think that only the male genitalia in their Fig. 53 belongs to *Euterpnosia* and others are misidentified. Yang and Chang (2000) did not observe an eversible part of vesica on the aedeagus of *E. gina*. Their observation is corresponding to mine on *E. varicolor*, *E. alpina*, and *E. madawdawensis*.

This study increases the number of Taiwanese *Euterpnosia* species up to thirteen. The high number of *Euterpnosia* species in Taiwan should be partly due to intense studies of the cicada fauna on the island by several authors and in contrast, much fewer studies and local specialists in the nearby regions, such as Southeast China. Future investigations on the continental regions could increase the number of species in *Euterpnosia* and give insight to the relationships and the origins of Taiwanese *Euterpnosia* species.

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太平姬春蟬之重新描述與臺灣產兩種新種姬春蟬（半翅目：蟬科）

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在檢查來自模式產地的太平姬春蟬（*Euterpnosia varicolor* Kato）的標本之後，作者發現在一篇最新的臺灣產蟬科訂正中一個姬春蟬屬的新種被錯誤鑑定並且被描述爲太平姬春蟬。因此作者根據來自模式產地的標本重新描述了太平姬春蟬並且描述了該新種以及另一個近緣的新種。作者描述了陽莖端部的膜狀囊以及骨化突起並證實這些構造在鑑別這三種姬春蟬時相當可靠。此外作者也分析了每種姬春蟬的鳴聲。最後作者討論了太平姬春蟬在分類上的問題，並在來自模式產地的太平姬春蟬標本中指定一隻雄蟬爲新模式以避免日後的混淆與錯誤鑑定。

關鍵詞：分類學，陽莖，新模式，鳴聲，膜狀囊。