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A New Species of the Cicada Genus *Euterpnosia* (Hemiptera: Cicadidae) from Taiwan, with Morphometric Approaches

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ABSTRACT

A new species of cicada, *Euterpnosia chilanensis* **sp. n.** (Hemiptera: Cicadidae: Cicadinae: Leptopsaltriini) is described from Northeastern Taiwan. The new species is morphologically similar to *E. hoppo* Matsumura, 1917, but can be distinguished using descriptive and morphometric methods. One qualitative and eight numeric diagnostic characters, all on the abdomen of the male, are provided for the differentiation of *E. chilanensis* **sp. n.** and *E. hoppo*, each of them being valid for clear-cut identification. A key using numeric diagnostic characters based on morphometrics is provided for the separation of *E. chilanensis* **sp. n.** from other *Euterpnosia* species distributed in Taiwan. Numeric diagnostic characters for some confused *Euterpnosia* species from Taiwan are also provided.

Key words: *Euterpnosia*, Cicadidae, Leptopsaltriini, new species, morphometrics

Introduction

The cicada genus *Euterpnosia* Matsumura, 1917 (Hemiptera: Cicadidae: Cicadinae: Leptopsaltriini) is widely distributed from India to East Asia (Chou *et al.* 1997, Lee and Hayashi 2003, Pham *et al.* 2010, Price *et al.* 2016). *Euterpnosia* species are small cicadas with slender body shapes. Males possess a pair of wart-like projections on the lateral side of the 4th abdominal tergum. The pygofer of the male is oval in ventral view, with a pair of well-developed ventral lobes; the aedeagus is very slender, far protruding from the uncus (Matsumura 1917, Lee and Hayashi 2003, Chen 2004, Pham *et al.* 2010). According to recent studies of the higher classification of Cicadidae, this genus belongs to the tribe Leptopsaltriini of the subfamily Cicadinae (Marshall *et al.* 2018) and is close to *Miniterpnosia* Lee, 2013 and *Yezoterpnosia* Matsumura, 1917 in morphology (Lee and Emery 2013) and molecular systematics (Hill *et al.* 2021), but can be easily separated from the latter two genera by a diagnostic character: males possess a pair of projections on the lateral side of the 4th abdominal tergum.

Euterpnosia species only inhabit old-growth

forests in Taiwan. Different *Euterpnosia* species occur at different altitudes ranging from 20 m to 2,500 m. Sixteen species, all endemic, have been reported from Taiwan (Lee and Hayashi 2003, Chen 2005, 2006, Chen and Shiao 2008), making *Euterpnosia* the most species-rich cicada genus on the island. During a plant survey trip in June 2010, we noticed calling songs of an unidentifiable cicada along the coastal road (Provincial Road No. 9) from Suao (蘇澳) to Wushipi Nature Reserve (烏石鼻自然保留區) in northeastern Taiwan. We conducted more surveys in 2013, 2014, and 2016 to collect the unknown species and recorded relevant ecological data. As a result, a new species of *Euterpnosia* was confirmed in the area and described in the present paper.

In addition to the formal description of the new species, another goal of our study was to provide morphological characters which can be used for clear-cut identification of the new species. Discrimination of species in the genus was traditionally based on descriptive morphology, frequently involving tedious comparisons. However, related species usually only exhibit subtle differences, rendering a qualitative morphological identification impossible, such as in the case of the 13-year and the 17-year periodical cicadas of the genus *Magicicada* Davis, 1925 mentioned by Simon (1983). Numeric morphometric methods have proved useful in discriminating morphologically highly similar taxa, for example, in the different broods of periodical cicadas (Simon 1983) and different subspecies of honeybees (Tofilski 2008). In this paper, we used both methods (i.e., descriptive and morphometric) to distinguish the new species from its allies.

Reliable identification of some morphologically similar *Euterpnosia* species is only possible based on genital characters (Chen 2005, Pham *et al.* 2010) involving time-consuming procedures, including relaxation and dissection. Such procedures always cause irreversible damage to specimens; thus, they might be undesirable or even impossible in some cases, e.g., in the case of type specimens. Besides, genitalia dissections require certain skills; therefore, researchers lacking the necessary background, such as ecologists or parataxonomists, might be unable to use genital characters. These circumstances motivated us to find more non-genital characters allowing a reliable identification of the *Euterpnosia* species from Taiwan.

Materials and Methods

Twelve specimens of the undescribed *Euterpnosia* species were collected, including 10 males and one female from Yilan County and one male from Hualien County, Taiwan. Specimens of other *Euterpnosia* species were examined in the National Museum of Natural Science, Taichung, Taiwan (NMNS), Taiwan Forestry Research Institute, Taipei, Taiwan (TFRI), and Department of Entomology, National Taiwan University, Taipei, Taiwan (NTU).

For quantify characters, wing-spread male specimens with a scale were photographed in a dorsal aspect using a digital camera (Canon 6D attached with a Canon EF 100 mm f2.8L Macro IS USM, mounted on a copy stand). Eighty-four points for measuring (Fig. 1) were set on every image of the specimen using the software tpsDig2 (Rohlf 2005). The first 30 points were set on one of the forewings (Fig. 1A), usually, the left one, unless abnormal venation was present. Distances between two points or the ratio of two distances were calculated using Microsoft Excel spreadsheets. Totally 71 morphometric characters (Table 1) were derived from the coordinate data of 84 points. To avoid redundancy and imprecision, we used codes (Table 1: X1-X71) to refer to morphometric characters instead of morphological terms. For each character of X1-X71, if the character ranges of two allied species or two groups did not overlap, the character was utilized as a valid diagnostic character (Fig. 2B, C). To achieve as high as possible accuracy rates for species identification, we used numeric diagnostic characters (NDCs) with the largest gap between two species or two groups (Fig. 2) to build the key. Certain character codes with their range were provided in parentheses in the species description, intended to serve as quantitative characters.

Male genitalia were examined and photographed with a tabletop scanning electron microscope (TM3000, Hitachi, Tokyo, Japan) and a light microscope.

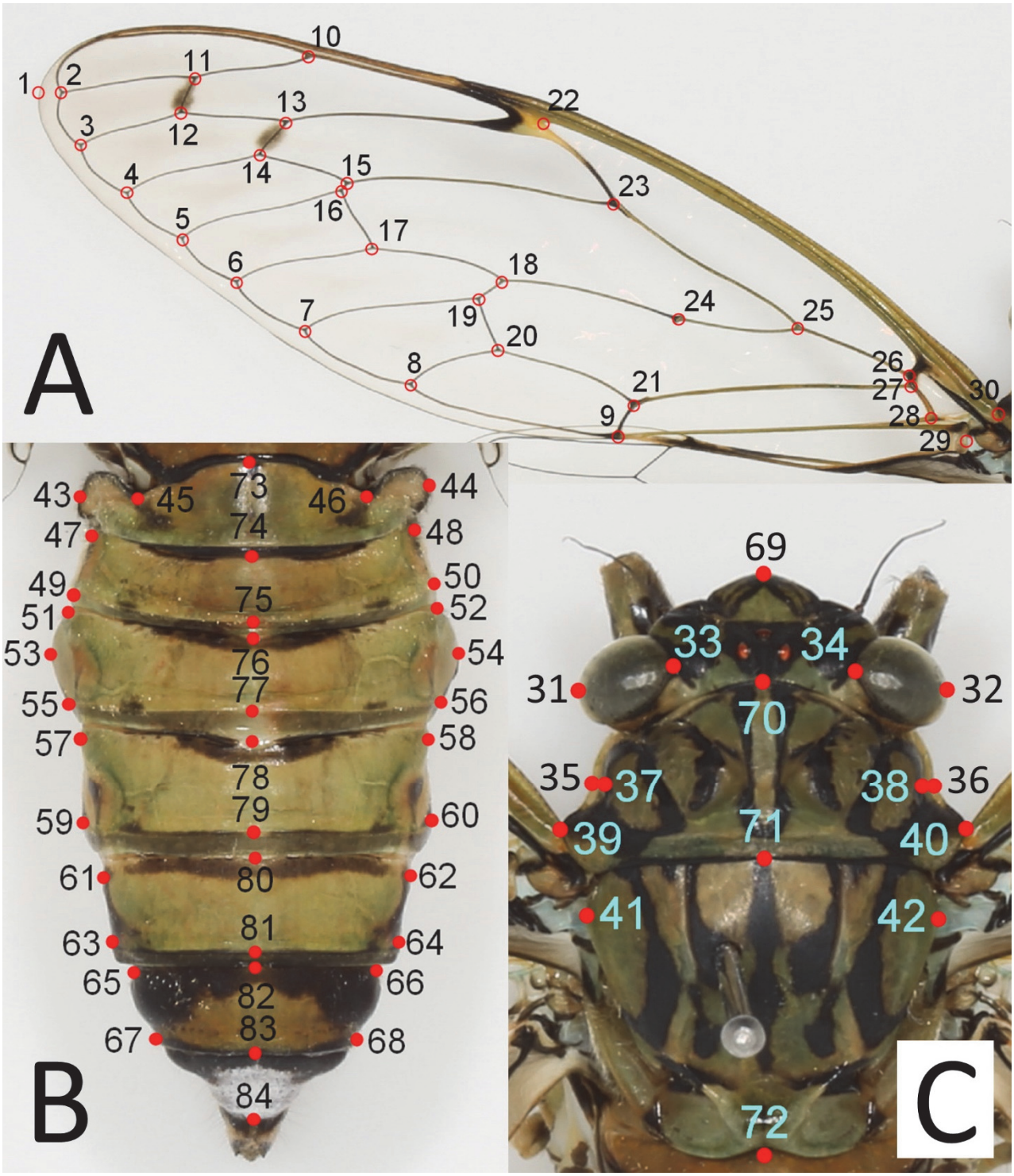

Fig. 1. Positions of 84 points for measuring the image of male *Euterpnosia chilanensis* **sp. n.**, holotype. (A) Forewing; (B) abdomen; (C) head and thorax.

Results

A total of 126 male specimens belonging to 15 *Euterpnosia* species were examined and measured (Table 2). No specimen was available for *E. gina* Kato, 1930, and *E. hohoguro* Kato, 1933. Among paired species (Table 2), there is no NDC for *E. olivacea* Kato, 1927 vs. *E. kotoshoensis* Kato, 1925, *E. varicolor* Kato, 1926 vs. *E. chishingsana* Chen and Shiao, 2008, and *E. varicolor* vs. *E. madawdawensis* Chen, 2005; only one NDC for *E. olivacea* vs. *E. koshunensis* Kato, 1927, and *E. varicolor* vs. *E. alpina* Chen, 2005. There are two NDCs for *E. hoppo* Matsumura, 1917 vs. *E. latacauta* Chen and Shiao, 2008. The results correspond to the

Table 1. Seventy-one morphometric characters produced by image measurements.

Character code	Distance or ratio	Position	Type	Character code	Distance or ratio	Position	Type
X1	1-30*	FW	Length	X36	43-44	A	Length
X2	1-30:8-22**	FW	Ratio	X37	43-44:73-74	A	Ratio
X3	24-30:1-30	FW	Ratio	X38	43-44:41-42	A	Ratio
X4	9-29:1-30	FW	Ratio	X39	45-46:43-44	A	Ratio
X5	2-9:1-30	FW	Ratio	X40	45-46:41-42	A	Ratio
X6	2-22:22-30	FW	Ratio	X41	47-48:41-42	A	Ratio
X7	23-25:25-26	FW	Ratio	X42	47-48:74-75	A	Ratio
X8	18-25:25-26	FW	Ratio	X43	47-48:43-44	A	Ratio
X9	22-23:23-25	FW	Ratio	X44	49-50:41-42	A	Ratio
X10	15-23:23-25	FW	Ratio	X45	49-50:74-75	A	Ratio
X11	18-24:24-25	FW	Ratio	X46	49-50:47-48	A	Ratio
X12	20-21:21-27	FW	Ratio	X47	51-52:41-42	A	Ratio
X13	2-11:11-10	FW	Ratio	X48	51-52:76-77	A	Ratio
X14	3-12:11-10	FW	Ratio	X49	53-54	A	Length
X15	4-14:13-22	FW	Ratio	X50	53-54:41-42	A	Ratio
X16	5-16:15-23	FW	Ratio	X51	53-54:76-77	A	Ratio
X17	6-17:17-18	FW	Ratio	X52	53-54:51-52	A	Ratio
X18	7-19:18-25	FW	Ratio	X53	57-58:41-42	A	Ratio
X19	8-20:20-21	FW	Ratio	X54	57-58:78-79	A	Ratio
X20	31-32	HT	Length	X55	57-58:53-54	A	Ratio
X21	31-32:69-70	HT	Ratio	X56	59-60:41-42	A	Ratio
X22	31-32:33-34	HT	Ratio	X57	59-60:78-79	A	Ratio
X23	31-32:35-36	HT	Ratio	X58	59-60:57-58	A	Ratio
X24	31-32:41-42	HT	Ratio	X59	61-62:41-42	A	Ratio
X25	35-36:70-71	HT	Ratio	X60	61-62:80-81	A	Ratio
X26	35-36:37-38	HT	Ratio	X61	61-62:59-60	A	Ratio
X27	35-36:39-40	HT	Ratio	X62	63-64:41-42	A	Ratio
X28	35-36:41-42	HT	Ratio	X63	63-64:80-81	A	Ratio
X29	37-38:70-71	HT	Ratio	X64	63-64:61-62	A	Ratio
X30	37-38:41-42	HT	Ratio	X65	65-66:82-83	A	Ratio
X31	39-40:70-71	HT	Ratio	X66	65-66:63-64	A	Ratio
X32	39-40:41-42	HT	Ratio	X67	67-68:82-83	A	Ratio
X33	41-42	HT	Length	X68	67-68:65-66	A	Ratio
X34	41-42:71-72	HT	Ratio	X69	69-72:1-30	HT, FW	Ratio
X35	41-42:69-72	HT	Ratio	X70	69-72:73-84	HT, A	Ratio
				X71	69-72:41-42	HT	Ratio

* 1-30 (number dash number) represents the distance between point 1 and point 30.

** 1-30: 8-22 represents the ratio of two distances. In the case of character X2, it indicates the ratio of the distance between point 1 and point 30 to the distance between point 8 and point 22.

Point positions are marked as in Fig. 3. FW: forewing; HT: head and thorax; A: abdomen.

phenotypic similarity in these pairs. For the new species and its allied species, all NDCs and criteria for diagnosis are listed in Table 3. Other useful NDCs for separating some sibling species are listed in Table 4, arranged by gap width in percentage.

Key to males of *Euterpnosia* species from Taiwan (except for *E. gina* and *E. hohoguro*)

Character codes are provided in Table 1. Parenthesized percentages after the value for a given character indicate the gap width compared to the total range of two groups or two species (Fig. 2); parenthesized texts represent descriptions of the given character in words. AT means abdominal tergum. *E. olivacea* displays considerable geographic variation in male genitalia (Chen 2008): a subapical projection on the inner side of the ventral lobe of the pygofer is present in most populations but absent in the northernmost part of Taiwan, i.e., populations from Hualien City and Taroko National Park. The key was designed to accommodate this variation.

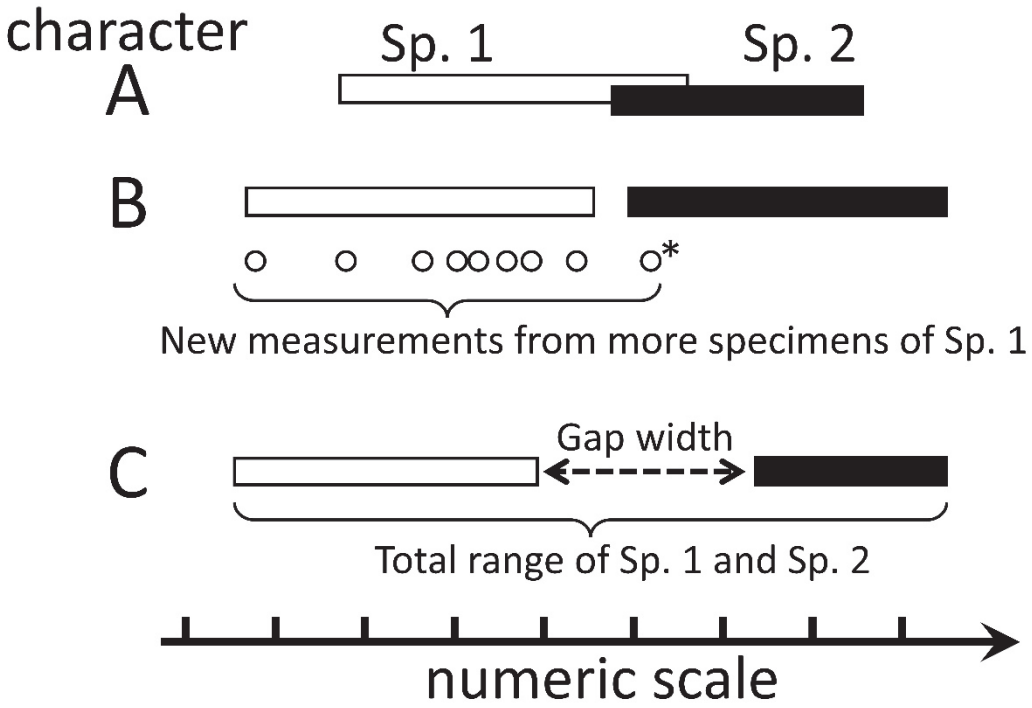

Fig. 2. Definition of numeric diagnostic character (NDC) and its gap. Hollow bars and black bars represent ranges of characters for species 1 and 2, respectively. Character A is not a NDC because the character ranges of the two species overlap. Both characters B and C are NDCs, but assumedly when more specimens of species 1 (open circles) are measured, the rightmost specimens (asterisked) would be incorrectly identified as species 2. In contrast, with a wider gap between two species, C is more reliable for diagnosis because character ranges of two species are less likely to overlap when increasing sample size.

Table 2. Number of numeric diagnostic characters on males between paired *Euterpnosia* species.

Species	*n*	*chilanensis*	*hoppo*	*latacauta*	*shuishana*	*olivacea*	*kotoshoensis*	*arisana*	*koshunensis*
chilanensis	11								
hoppo	14	8							
latacauta	4	9	2						
shuishana	4	9	11	12					
olivacea	19	12	10	5	13				
kotoshoensis	12	12	11	8	14	0			
arisana	3	25	17	14	23	9	12		
koshunensis	5	25	15	23	32	1	5	25	
viridifrons	5	28	26	31	35	14	22	25	20

Species	*n*	*chilanensis*	*varicolor*	*chishingsana*	*madawdawensis*	*alpina*	*laii*
varicolor	25	10					
chishingsana	3	23	0				
madawdawensis	4	21	0	13			
alpina	17	18	1	12	4		
laii	2	39	5	39	27	18	
ampla	2	23	10	39	26	7	47

n: sample size.

1. X59 < 0.82 (14%) (base of 6th AT narrower) ..... *E. viridifrons*
- X59 > 0.82 (14%) (base of 6th AT wider) .. (2)
2. Ventral lobe of male pygofer without subapical projection on inner side..... (3)
- Ventral lobe of male pygofer with subapical projection on inner side..... (9)
3. X23 > 1.06 (9%) (Head wider)..... .....*E. olivacea* or *E. kotoshoensis*
- X23 < 1.06 (9%) (Head narrower) .... *E. varicolor* species group (4)
4. X49 > 10.15 (24%) (width of 4th AT more

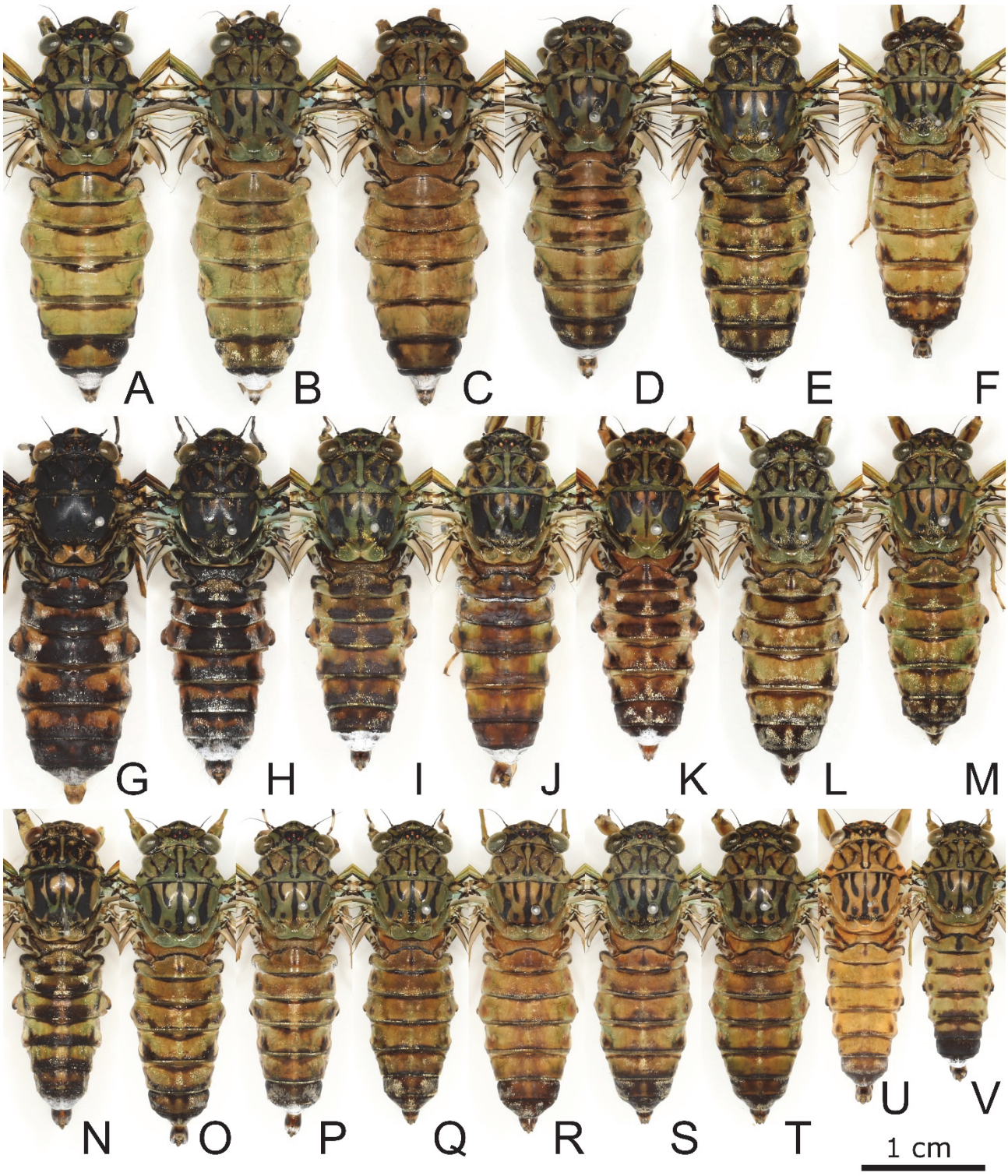

Fig. 3. *Euterpnosia* males in dorsal view. The scale bar is 1 cm.
(A) *E. chilanensis* **sp. n.**, holotype, NMNS; (B-D) *E. chilanensis* **sp. n.**, paratypes, NMNS; (E) *E. hoppo* from Fushan Botanical Garden, Yilan Co., NMNS; (F) *E. latacauta*, paratype, topotypic specimen, NTU; (G) *E. ampla*, paratype, topotypic specimen, NMNS; (H) *E. alpina*, holotype, NMNS; (I) *E. varicolor*, topotypic specimen, NMNS; (J) *E. chishingsana*, holotype, NTU; (K) *E. madawdawensis,* holotype, NMNS; (L) *E. shuishana*, from Lianhuachih, Nantou Co., near the type locality, NMNS; (M) *E. arisana*, topotypic specimen, NMNS; (N) *E. laii*, topotypic specimen, NTU; (O) *E. sp.* from southeastern Taiwan, NMNS; (P) *E. koshunensis*, topotypic specimen, NMNS; (Q) *E. olivacea* from Shouka, Pingtung Co., near the type locality, NMNS; (R) *E. olivacea* from Hsincheng, Hualien Co., NMNS; (S, T) *E. kotoshoensis*, topotypic specimens, NMNS; (U) *E. viridifrons*, from northern Taiwan, NMNS; (V) *E. viridifrons*, from southern Taiwan, NMNS.

Table 3. All numeric diagnostic characters on males for *Euterpnosia chilanensis* **sp. n.**, *E. hoppo*, *E. latacauta*, and *E. shuishana*. See Table 1 for character codes.

Character code	Range of species *chilanensis* (n = 11)	Range of species *hoppo* (n = 14)	MG	Criteria for diagnosis < MG	Criteria for diagnosis > MG	Gap width between species	Gap width (%)	Position of character
X49	10.41-11.82	9.15-10.19	10.301	*hoppo*	*chilanensis*	0.225	8.4	4th AT
X50	1.42-1.50	1.27-1.41	1.415	*hoppo*	*chilanensis*	0.006	2.7	4th AT
X52	1.104-1.158	1.043-1.095	1.100	*hoppo*	*chilanensis*	0.008	7.4	4th AT
X55	0.78-0.87	0.89-0.92	0.879	*chilanensis*	*hoppo*	0.027	18.9	5th AT
X61	0.86-0.89	0.90-0.94	0.898	*chilanensis*	*hoppo*	0.011	13.2	6th AT
X66*	0.84-0.89	0.92-0.95	0.904	*chilanensis*	*hoppo*	0.031	28.4	7th AT
X67	1.84-2.35	2.60-2.87	2.475	*chilanensis*	*hoppo*	0.245	23.9	7th AT
X68	0.72-0.83	0.87-0.92	0.852	*chilanensis*	*hoppo*	0.043	21.8	7th AT
	chilanensis (n = 11)	*latacauta* (n = 4)	MG	< MG	> MG			
X33	7.094-7.946	6.425-7.068	7.081	*latacauta*	*chilanensis*	0.026	1.7	Mesonotum
X36	8.76-10.02	7.748-8.355	8.555	*latacauta*	*chilanensis*	0.399	17.6	2nd AT
X37	3.665-4.109	3.469-3.580	3.622	*latacauta*	*chilanensis*	0.085	13.3	2nd AT
X49	10.41-11.82	8.995-9.568	9.991	*latacauta*	*chilanensis*	0.846	30.0	4th AT
X50	1.418-1.503	1.338-1.400	1.409	*latacauta*	*chilanensis*	0.018	11.1	4th AT
X66*	0.840-0.888	0.934-0.954	0.911	*chilanensis*	*latacauta*	0.046	40.5	7th AT
X67	1.844-2.352	2.618-3.319	2.485	*chilanensis*	*latacauta*	0.266	18.0	7th AT
X68	0.720-0.830	0.888-0.915	0.859	*chilanensis*	*latacauta*	0.057	29.3	7th AT
X69	0.343-0.373	0.324-0.336	0.339	*latacauta*	*chilanensis*	0.007	14.7	Forewing
	chilanensis (n = 11)	*shuishana* (n = 4)	MG	< MG	> MG			
X6	0.862-0.966	0.835-0.852	0.857	*shuishana*	*chilanensis*	0.010	7.6	Forewing
X26	1.043-1.084	1.107-1.117	1.095	*chilanensis*	*shuishana*	0.023	32.0	Pronotum
X27*	0.831-0.861	0.885-0.898	0.873	*chilanensis*	*shuishana*	0.024	35.7	Pronotum
X33	7.094-7.946	6.535-7.050	7.072	*shuishana*	*chilanensis*	0.044	3.1	Mesonotum
X36	8.755-10.02	7.875-8.426	8.590	*shuishana*	*chilanensis*	0.328	15.3	2nd AT
X37	3.665-4.109	3.265-3.504	3.584	*shuishana*	*chilanensis*	0.161	19.1	2nd AT
X38	1.209-1.292	1.182-1.209	1.2094	*shuishana*	*chilanensis*	0.0001	0.1	2nd AT
X49	10.41-11.82	9.271-9.914	10.164	*shuishana*	*chilanensis*	0.500	19.6	4th AT
X66	0.840-0.888	0.915-0.940	0.902	*chilanensis*	*shuishana*	0.027	27.0	7th AT

* The character with the largest gap width between two species, i.e., the most reliable character for diagnosis. MG: Midpoint of gap. AT: abdominal tergum. For those characters regarding length such as X33, X36, and X49, the unit is mm. For other characters regarding ratio, their values are ratios without unit. Gap width in percentage is the gap width divided by the total range of two species.

than 10.15 mm)·····*E. ampla*

- X49 < 10.15 (24%) (width of 4th AT less than 10.15 mm)····· (5)

5 X36 < 7.03 (7%) (width of 2nd AT less than 7.03 mm)·····*E. laii*

- X36 > 7.03 (7%) (width of 2nd AT more than 7.03 mm)····· (6)

6 X15 > 0.956 (7%) (Venation of forewing) ····· ····· *E. alpina*

- X15 < 0.956 (7%) (Venation of forewing) ·· (7)

7 From Datun Volcano Group ····· ····· *E. chishingsana*

- Not from Datun Volcano Group ····· (8)

8 From Coastal Range in Eastern Taiwan····· ····· *E. madawdawensis*

- From mountains in Northern Taiwan ····· ····· *E. varicolor*

9. X62 < 0.90 (7%) (lower part of 6th AT narrower) ····· (10)

- X62 > 0.90 (7%) (lower part of 6th AT wider) ····· (12)

10. X52 > 1.155 (41%) (lateral projection of 4th AT more protruded)····· *E. arisana*

- X52 < 1.155 (41%) (lateral projection of 4th AT less protruded)····· (11)

11. X61 > 0.897 (8%) (projection on lateral side of 5th AT smaller) ·····*E. koshunensis*

- X61 < 0.897 (8%) (projection on lateral side of 5th AT larger)····· ·····*E. olivacea* or *E. kotoshoensis*

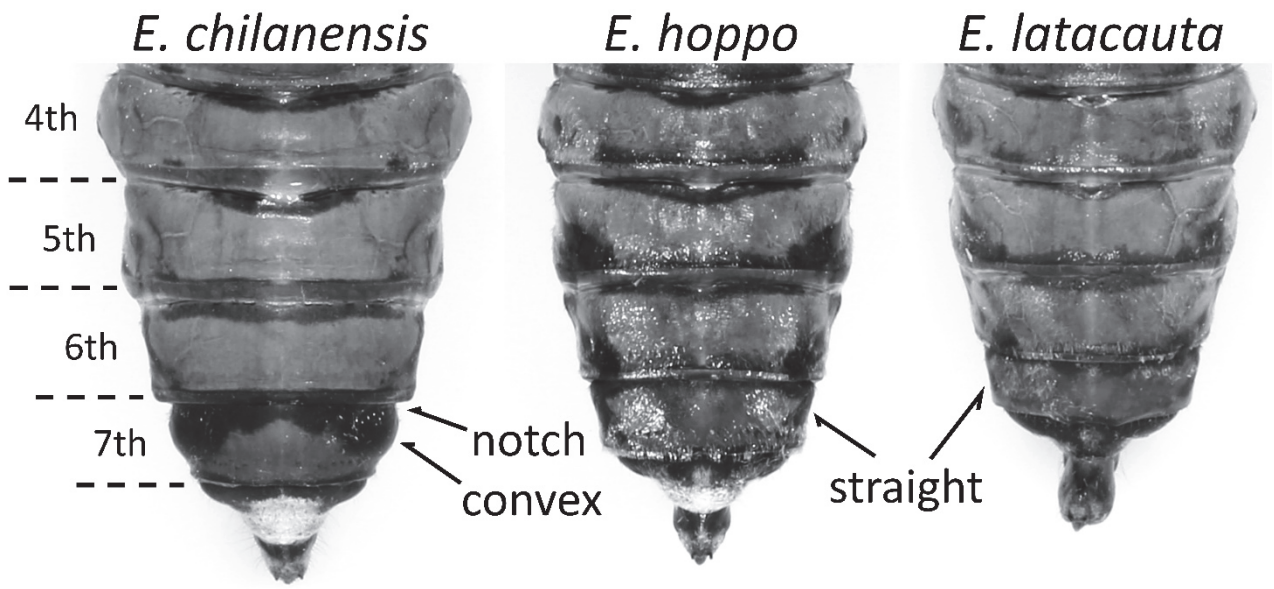

Fig. 4. The diagnostic character for *Euterpnosia chilanensis* **sp. n.** The 7th abdominal tergum is convex laterally for *E. chilanensis* but not convex laterally for *E. hoppo* and *E. latacauta*.

12. X66 < 0.90 (24%) (base of 7th AT narrower) ·····*E. chilanensis* **sp. n.**
- X66 > 0.90 (24%) (base of 7th AT wider)····· ····· (13)
13. X68 < 0.85 (41%) (shape of 7th AT) ····· ·····*E. shuishana*
- X68 > 0.85 (41%) (shape of 7th AT) ····· (14)
14. X69 > 0.34 (17%) (Forewing shorter)····· ·····*E. hoppo*
- X69 < 0.34 (17%) (Forewing longer) ····· ·····*E. latacauta*

Euterpnosia chilanensis, Chen, Hsieh, Chen, Chen & Chang, **sp. n.**
(Fig. 1, 3A-D, 4-8; Table 2, 3, 5)
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Diagnosis. Similar to *E. hoppo* and *E. latacauta* (Fig. 3), but males can be distinguished from those of the latter two species by the 7th abdominal tergum being laterally convex, forming an obvious notch between the 6th and 7th abdominal tergum (Fig. 4); the 7th abdominal tergum is laterally straight in the above mentioned two species (Fig. 4).

According to numeric diagnostic characters (NDCs) between paired species (Table 2), males of the new species are most similar to those of *E. hoppo*, but eight NDCs can be recognized for them (Table 2, 3), including a wider 4th abdominal tergum (X49, X50, X52) and more tapering 5th-7th abdominal terga (X55, X61, X66-X68) for *E. chilanensis*. Of these eight NDCs, X66 is the most reliable one (Table 3); this character can separate the new species from *E. latacauta* and *E. shuishana* as well (Table 3). No reliable morphology-based identification is currently possible for females.

Description. Male. Head slightly wider than pronotum (Fig. 1, X23 = 1.02-1.09); vertex greenish to olivaceous, with an inverted pentagonal black spot medially and a pair of irregular black marks between lateral ocelli and eyes; ocelli usually red or pink, sometimes green or yellow; postclypeus protruding anteriorly, with a green triangular spot in front of central ocellus in dorsal view and a U- or V-shaped black fascia situated centrally in ventral view; anteclypeus yellowish-green, hairy, with a black mark medially; rostrum yellowish-green, with a black tip, extending to coxa of the hind leg.

Pronotum width subequal to mesonotum width (Fig. 1, X28 = 0.95-1.01). Pronotum greenish to olivaceous, with a pair of longitudinal black fasciae submedially, bearing black fasciae along oblique fissures and ambient fissure; pronotal collar wider than mesonotum width (Fig. 1, X32 = 1.14-1.17), greenish to olivaceous, with two black spots on each posterolateral lobe (lateral angle).

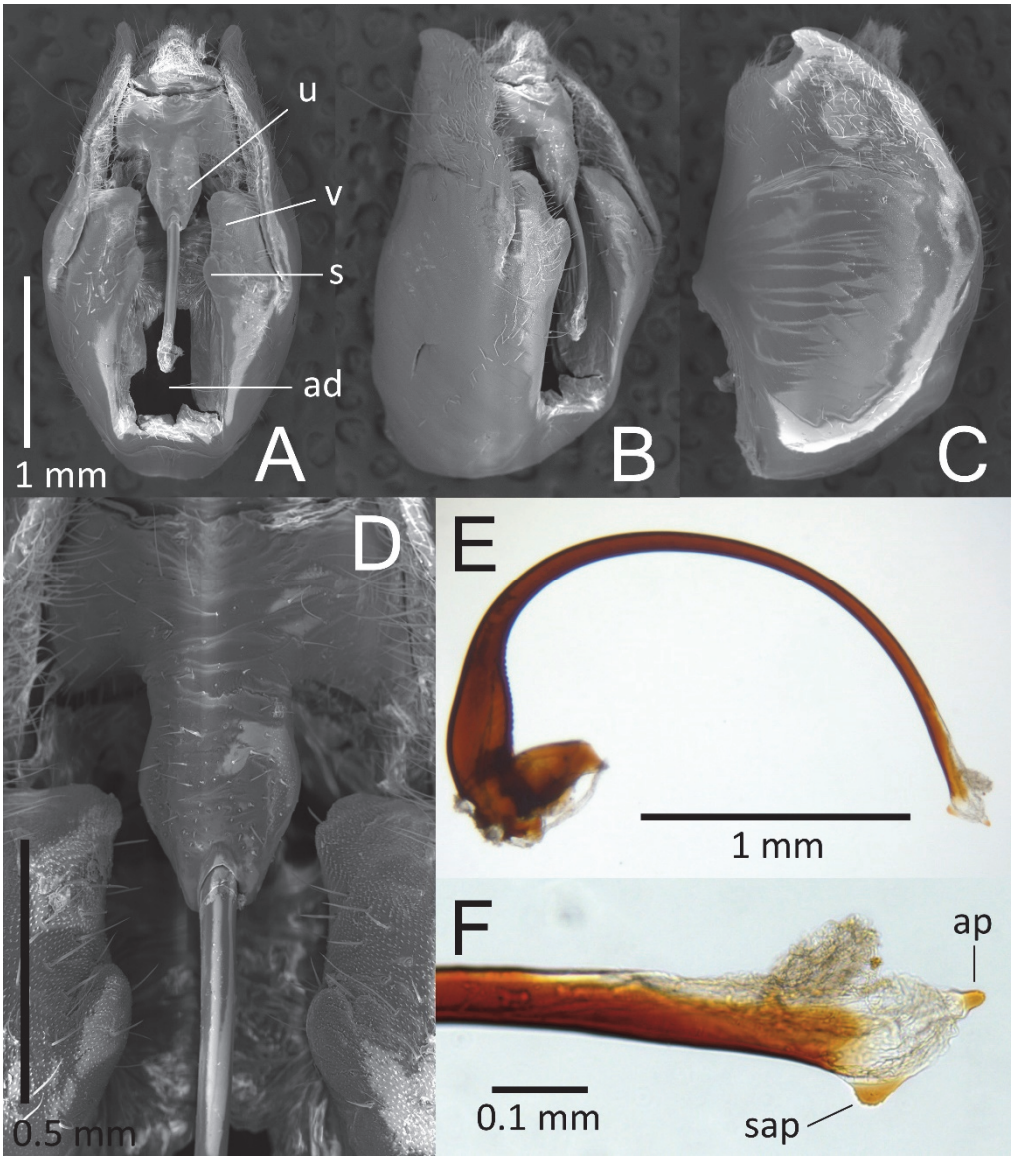

Fig. 5. Male genitalia of *Euterpnosia chilanensis* **sp. n.**, paratype. (A) Ventral view; (B) ventral-lateral view; (C) lateral view; (D) uncus in ventral view; (E) aedeagus in lateral view; (F) apical part of aedeagus in lateral view; (A-D) by SEM; (E-F) by light microscopy; (ad) artificial damage; (ap) apical projection; (s) subapical projection of ventral lobe; (sap) subapical projection; (u) uncus; (v) ventral lobe.

Mesonotum greenish to olivaceous, with a black longitudinal median fascia, an arcuate black mark on the inner area of each longitudinal fissure, a black oblique fascia on each sublateral area, and a small black spot in front of each side of cruciform elevation; cruciform elevation greenish to olivaceous, with a black shoulder on each side, sometimes bearing a thin and vague median fascia. Operculum greenish-yellow, short, reniform; margin of operculum round, sometimes black edged.

Wings (Fig. 1) hyaline; wing veins black; forewing spotted with infuscations on 1st and 2nd cross-veins, some individuals with faint infuscation on 3rd cross vein as well.

Abdomen olivaceous, spear-like, clothed with sparse golden pilosity dorsally; black narrow transverse fasciae present on anterior edges of 3rd to 7th terga; a small black spot present on each lateral area of 3rd to 7th terga in lateral view. On some individuals, a pair of black rectangle spots present on the 2nd, 3rd, and 4th terga submedially (Fig. 3D). Tymbal covers small, black-edged, exposing timbal in dorsal view. 4th tergum very wide (X49 = 10.41-11.82 mm), much wider than mesonotum (X50 = 1.42-1.50). Projection on each lateral side of 4th tergum large (Fig. 4, X52 = 1.10-1.16), with black and thickened tip. 7th tergum convex laterally (Fig. 4). 8th tergum usually covered with white

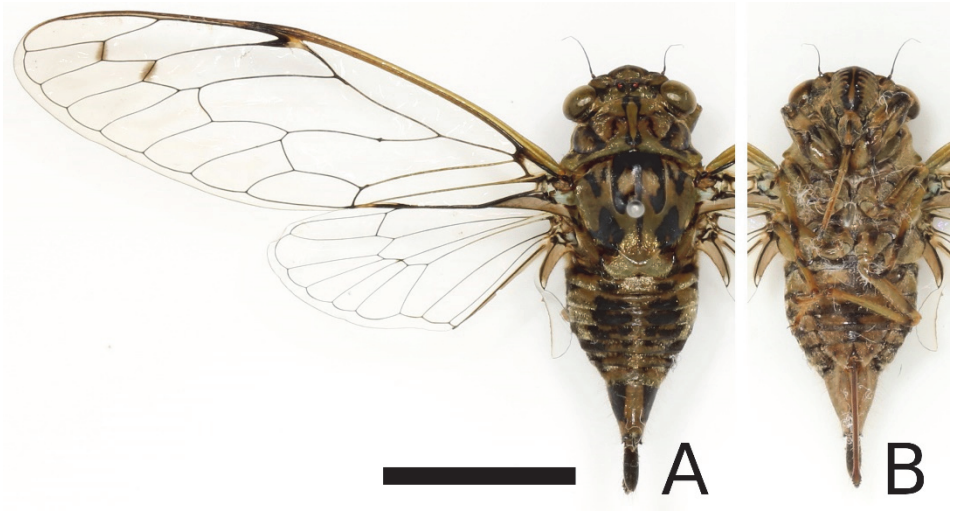

Fig. 6. Female *Euterpnosia chilanensis* **sp. n.**, paratype. (A) Dorsal view. (B) Ventral view. The scale bar is 1 cm.

wax (Fig. 3A-D). Venter of abdomen olivaceous to brownish, slightly translucent; spiracle white, connected to a dark base; sterna covered with erect short hairs and sparse white wax.

Male genitalia (Fig. 5). Pygofer oval; uncus lobe slightly narrowed at base; inner edge of each ventral lobe bearing a small subapical projection; aedeagus reddish brown, slender, with an inflated base; apical part of aedeagus bearing one apical and one subapical sclerotized projection; both projections flat, edge slightly indented.

Female (Fig. 6). Similar to male in coloration of head and thorax but much smaller in body size (Table 5). Abdomen brown to olivaceous, covered by some sparkled short hairs, with a pair of transversal black spots on 2nd to 6th abdominal segments. Lateral area of 9th abdominal segment black. Posterior end of 9th abdominal segment including dorsal beak black. Ovipositor sheath black, protruding much beyond 9th abdominal segment.

Calling songs. Mainly composed of repeated "mew" sound accompanied by a continuous buzzing. Sound intensity increases gradually during one complete sequence, maintains steady, and then fades out (Fig. 7A). Such a sequence can repeat several times until mute. When a "mew" raises, sound energy boosts up (Fig. 7B) and shifts into harmonic bands with a peak at about 4.1 kHz (Fig. 7C). In the climax part of one sequence (Fig. 7A), "mew" repeats 1.8-2.0 times per second (n = 4). For human's auditory sense, the calling song of *E. chilanensis* **sp. n.** is unique and cannot be confused with other Taiwanese cicadas; it is coincidentally somewhat similar to that of *Meimuna oshimensis* (Matsumura, 1906), a species endemic to Okinawa Island, Japan.

Measurements. See Table 5 for details.

Type material. Holotype ♂, YILAN: Chilan Forest Recreation Area, 23-IV-2014, Wei-Jen Chen. Paratypes: YILAN: Chilan Forest Recreation Area, 4 ♂ 1 ♀, 23-IV-2014, Wei-Jen Chen; Nan-ao Hsiang, Guanyin, 1 ♂, 22-VI-2014, Tung-Yu Hsieh; Same location, 1 ♂, 3-VI-2016, Jian-Hong Chen; Same location, 1 ♂, 5-VI-2016, Jian-Hong Chen. HUALIEN: Sholin Hsiang, Heping Forest Road, 1 ♂, 4-VI-2016, Jian-Hong Chen. All type specimens are deposited in the NMNS.

Etymology. Named after the type locality, Chilan Forest Recreation Area, Yilan County, Taiwan.

Distribution. Only known from northeastern Taiwan (Fig. 8B). In addition to the type locality, the chorus was detected sporadically along the coastal road from Suao Port (Yilan County) to Heping Port (Hualien County). A population was found at Jiuzhize Hot Spring, Yilan County, near the type locality.

Ecology. This species inhabits only primary broad-leaved forests dominated by *Ficus* and

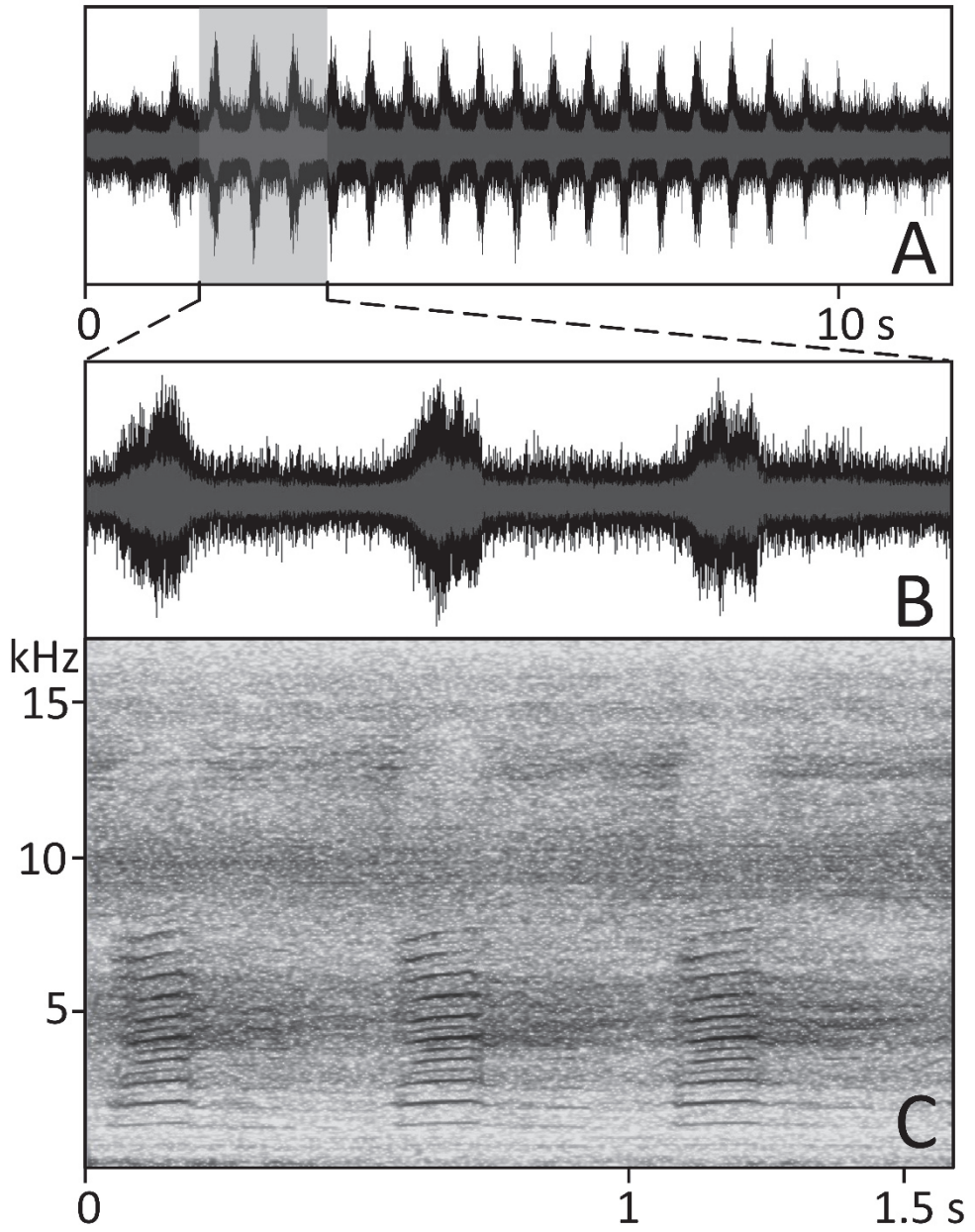

Fig. 7. Calling song of *Euterpnosia chilanensis* **sp. n.** from Guanyin, Nan-ao Hsiang, Yilan County. (A) Oscillogram of the climax part of calling. (B) Oscillogram and (C) spectrogram of zoomed segment A, showing three frequency shifts or "mews".

Machilus trees (Fig. 8C, D), ranging from 200-800 m altitude above sea level (Fig. 8B). Adults occur from April to June. Males often aggregate and chorus on the high canopy of large *Machilus* trees in the daytime, even in the rain. According to field observations in Guanyin (Fig. 8D), *E. chilanensis* **sp. n.** is sympatric with several cicada species, including *E. viridifrons* Matsumura, 1917, *Semia watanabei* (Matsumura, 1907), *Pomponia yayeyamana* Kato, 1933, and *Vagitanus terminalis* (Matsumura, 1913).

Discussion

Our methods successfully separate some very similar species (Table 4) without using genital characters. However, we still cannot find any NDC for some species pairs, such as *E. olivacea* vs. *E. kotoshoensis*, *E. varicolor* vs. *E. chishingsana*, and *E. varicolor* vs. *E. madawdawensis* (Table 2). To separate these species, additional information, including genital morphology and acoustic characters remain necessary (Chen 2005, Chen and Shiao 2008).

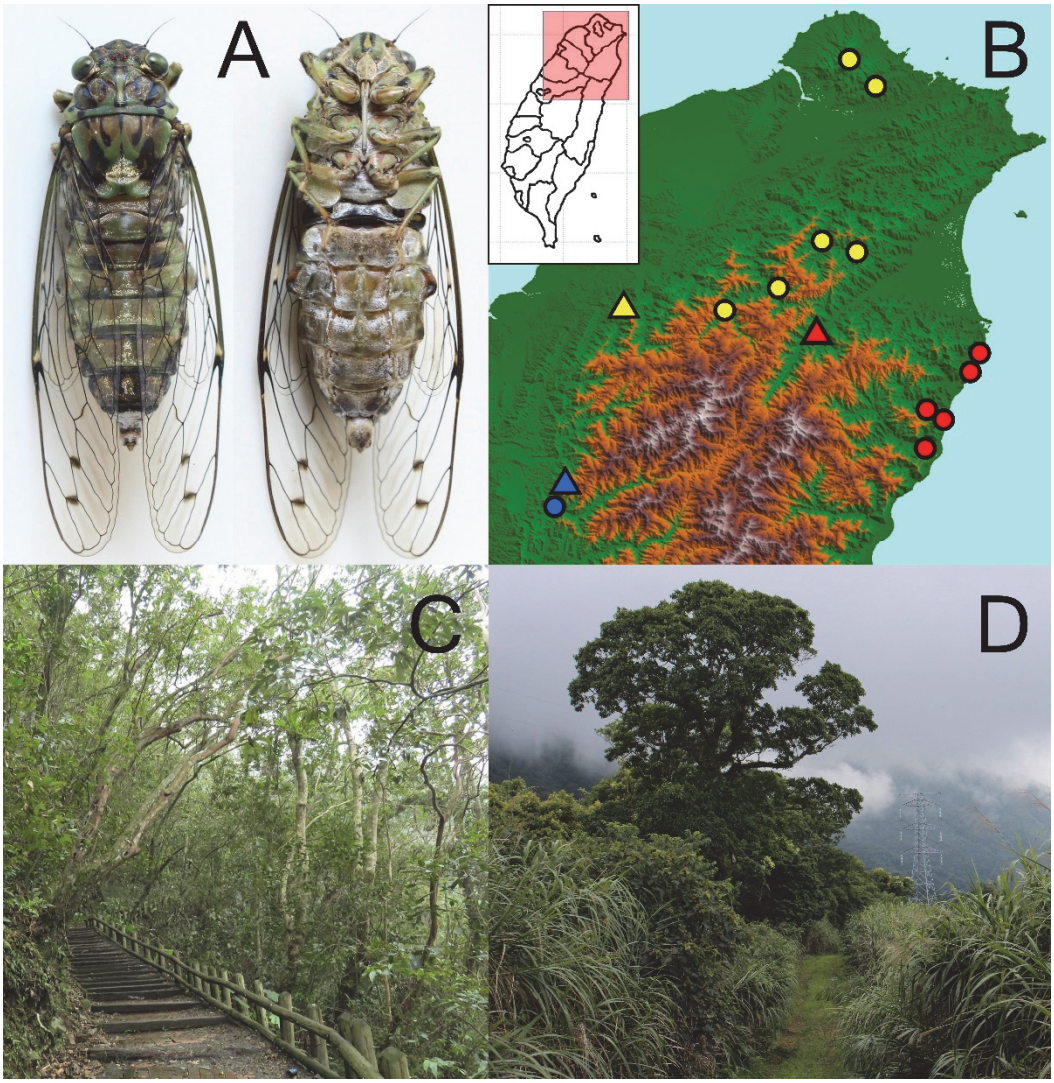

Fig. 8. (A) The coloration of *Euterpnosia chilanensis* **sp. n.** while the specimen is not dried out, paratype male. (B) Distribution of *E. chilanensis* **sp. n.** (red symbols), *E. hoppo* (yellow symbols), and *E. latacauta* (blue symbols). Triangles indicate type localities. The mountain area higher than 1500 m in altitude is shown in brownish color. (C) Habitats of *E. chilanensis* **sp. n.** in the type locality, Chilan, Yilan County. (D) Habitats of *E. chilanensis* **sp. n.** in Guanyin, Nan-ao Hsiang, Yilan County. The tallest tree in the picture is *Machilus sp.* (Lauraceae), likely a host plant, on which male *E. chilanensis* **sp. n.** aggregate and call.

Differences in genital morphology have long been recognized as a possible reproductive isolation mechanism in many insect groups. However, we cannot find any difference in the male genitalia of *E. chilanensis* **sp. n.** and *E. hoppo*. In contrast, the shape of the male pregenital abdomen of *E. chilanensis* **sp. n.** is quite different from that of *E. hoppo* and other allied species, such as *E. latacauta* and *E. shuishana* (Fig. 3, 4, Table 3). Mate-attracting signals, such as calling songs produced by male cicadas to attract females, often distinguish closest species more effectively than do genitalia (Alexander *et al.* 1997). The hollow abdomen of male cicadas functions as a Helmholtz resonator and may play a key role in species recognition and pre-mating isolation; thus, it could evolve more rapidly than male genitalia.

Different *Euterpnosia* species usually have different shapes of the male abdomen (Fig. 3), so species delimitation is not too difficult. In the case of *E. chilanensis* **sp. n.** and *E. hoppo*, a single NDC is sufficient to separate them. However, it is impossible to separate cryptic species by single morphological character for some highly difficult taxa, such as the *Cicadetta montana* species complex (Hertach *et al.* 2015). In such cases, a multivariate analysis may provide a solution (Simon 1983). The second author of this paper attempts to apply

Table 4. Numeric diagnostic characters with larger gap for some paired sibling *Euterpnosia* species which are easy to be confused. See Table 1 for character codes and Table 3 for footnotes.

Character code	Range of species		MG	Criteria for diagnosis		Gap width between species	Gap width (%)	Position of character
	hoppo (*n* = 14)	*latacauta* (*n* = 4)		< MG	> MG			
X69*	0.344-0.374	0.324-0.336	0.340	*latacauta*	*hoppo*	0.009	17.2	Forewing
X36	8.612-9.417	7.748-8.355	8.484	*latacauta*	*hoppo*	0.257	15.4	2nd AT
	olivacea (*n* = 19)	*koshunensis* (*n* = 5)	MG	< MG	> MG			
X61*	0.847-0.893	0.901-0.941	0.897	*olivacea*	*koshunensis*	0.008	8.8	5th AT
	varicolor (*n* = 25)	*alpina* (*n* = 17)	MG	< MG	> MG			
X15*	0.620-0.930	0.983-1.393	0.956	*varicolor*	*alpina*	0.053	6.9	Forewing
	varicolor (*n* = 25)	*ampla* (*n* = 2)	MG	< MG	> MG			
X49*	8.13-9.46	10.59-10.94	10.027	*varicolor*	*ampla*	1.134	40.5	4th AT
X56	0.988-1.149	1.235-1.343	1.192	*varicolor*	*ampla*	0.086	24.1	5th AT
X59	0.853-1.024	1.108-1.218	1.066	*varicolor*	*ampla*	0.083	22.9	6th AT
X62	0.754-0.922	0.988-1.092	0.955	*varicolor*	*ampla*	0.066	19.5	6th AT
X53	0.949-1.095	1.141-1.257	1.118	*varicolor*	*ampla*	0.047	15.2	5th AT
X11	0.885-1.653	0.672-0.740	0.812	*ampla*	*varicolor*	0.145	14.8	Forewing
X50	1.234-1.383	1.422-1.522	1.403	*varicolor*	*ampla*	0.039	13.4	4th AT
	alpina (*n* = 17)	*ampla* (*n* = 2)	MG	< MG	> MG			
X49*	8.59-9.70	10.59-10.94	10.148	*alpina*	*ampla*	1.134	38.1	4th AT
X68	0.901-0.972	0.868-0.869	0.885	*ampla*	*alpina*	0.032	30.5	7th AT
	alpina (*n* = 17)	*madawdawensis* (*n* = 4)	MG	< MG	> MG			
X15*	0.983-1.393	0.761-0.879	0.931	*madawdawensis*	*alpina*	0.104	16.5	Forewing
X12	0.321-0.411	0.439-0.499	0.425	*alpina*	*madawdawensis*	0.028	15.9	Forewing

Table 5. Measurements on types of *Euterpnosia chilanensis* **sp. n.**

Variables (mm)	Holotype (n = 1)	Type males (n = 11)	Paratype female (n = 1)
Body length	31.5	31.5-29.2	22.3
Head and thorax length	12.0	13.1-10.9	11.0
Abdomen length	19.4	19.7-17.4	11.2
Head width	7.8	8.2-7.2	7.0
Thorax width	7.5	8.0-7.1	6.3
Abdominal width*	10.8	11.8-10.4	6.8
Forewing length	32.7	35.3-32.0	29.2
Wing-spread width	71.8	74.7-69.9	65.1

* The widest width of abdomen.

multivariate analysis on morphometric data of Taiwanese *Euterpnosia* species. The result will be published later and may give insight into the taxonomy of difficult cicada species complexes, such as *Tanna sozanensis* Kato, 1926, *T. taipinensis* (Matsumura, 1907), *T. auripennis* Kato, 1930, *T. sayurie* Kato, 1926, and *T. karenkonis* Kato, 1939, etc., which have very few interspecific differences (Lee and Hayashi 2004).

Notes on other *Euterpnosia* species

No NDC suitable for discrimination of *E. olivacea* and *E. kotoshoensis* (Table 2) was found. The former is widely distributed along the low land region of eastern Taiwan, extended from Taroko National Park, Hualien County (Chen 2008) to Nanjenshan Nature Reserve, Pingtung County (personal observation). The latter is endemic to Lanyu Island, which lies southeast of Taiwan Island with the nearest distance of 62

km. The close distribution and lack of distinguishing characters in the male genitalia, calling songs, and ecology make these two species likely identical. Multivariate analysis of morphological data and a molecular study are necessary to test this hypothesis.

E. varicolor and *E. chishingsana* are also very similar in male morphology and calling songs (Chen and Shiao 2008). Our analyses cannot find any diagnostic characters for their separation (Table 2). However, they are geographically well isolated: *E. chishingsana* inhabits only the top regions of the Datun Volcano Group, far away from the localities of *E. varicolor*. In addition, the call of *E. chishingsana* is much faster than that of *E. varicolor* (130 vs. 86.5 ± 10.1 frequency band modulated phrase per minute) (Chen 2005, Chen and Shiao 2008). These suggest that they are likely two phylogenetically closely related but distinct species or at least subspecies.

No NDC was found for separating *E. varicolor* and *E. madawdawensis* either (Table 2). Their very distinct male calling songs and slightly different male genitalia (Chen 2005) support that they are different at the species level.

A single NDC was found for separating *E. varicolor* and *E. alpina* (Table 2, 4). These two species, however, are distinct in male genitalia, male calling songs, range of altitude, and host plants (Chen 2005). They are undoubtedly distinct species and can hardly be confused, especially when calling males audible.

Its large body size, much wider male abdomen (Fig. 3), and most NDCs (Table 2) make *E. ampla* a very distinctive member of the *E. varicolor* species group. Our analyses show that *E. ampla* is most similar to *E. alpina*; 7 NDCs were found between them (Table 2). These two species are also different in the structure of the aedeagus (Chen 2006). Chen *et al.* (2010) recorded *E. ampla* from Taroko National Park and noticed a difference between its calling song and that of *E. alpina*. They are also well isolated in ecology: in Taroko National Park, *E. ampla* inhabits broad-leaf forests in the altitude ranging from 1,600 to 2,200 m (Chen *et al.* 2010), but *E. alpina* inhabits coniferous forests at the altitude ranging from 2,200 to 2,500 m (personal observation). This indicates that they are different at the species level.

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臺灣的新蟬種－棲蘭姬春蟬(半翅目：蟬科)－兼以形態測定法來進行判別

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摘　要

本文描述了一種產於臺灣東北部的新種－棲蘭姬春蟬 (*Euterpnosia chilanensis* **sp. n.**)。本種形態上與北埔姬春蟬 (*E. hoppo* Matsumura, 1917) 最為近似但可經由描述法與形態測定法區別。我們共發現 1 個視覺診斷特徵及 8 個數值診斷特徵，這些特徵都在雄蟲腹部，每一個皆可用來明確地鑑別棲蘭姬春蟬與北埔姬春蟬。為了區別棲蘭姬春蟬與臺灣其他種類的姬春蟬，我們利用基於形態測定法所發現的數值診斷特徵來建立檢索表。此外，對於一些產自臺灣且容易混淆的姬春蟬物種，我們也提供了數值診斷特徵。

關鍵詞：姬春蟬屬、蟬科、小蟬族、新種、形態測量學