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Morphology and Character Evaluation of Scales in Scaly Crickets (Orthoptera: Grylloidea: Mogoplistidae)

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Jeng-Tze Yang and Fang-Shen Yen (2001) Morphology and character evaluation of scales in scaly crickets (Orthoptera: Grylloidea: Mogoplistidae). *Zoological Studies* **40**(3): 247-253. This work investigates the peculiar structure of scales on the disc and posterior margin of the pronotum from 10 species of Taiwanese scaly crickets using scanning electron microscopy (SEM). Properties of the scales are also described and illustrated using SEM photography. The feasibility of using scale structure as a morphological character for taxonomic studies in mogoplistid crickets is evaluated using Duncan's multiple range tests. http://www.sinica.edu.tw/zool/zoolstud/40.3/247.pdf

Key words: Mogoplistidae, SEM-photography, Scales, Taiwan, Ultra-structure.

The family name Mogoplistidae comes from the generic name *Mogoplistes* originally erected by Serville in 1838 (Rentz 1996). The Chinese name for Mogoplistidae is *hua-lang*, which literally translates as "flower bell" (Yin and Liu 1995, Jin 1996). In the Western literature, they are called scaly crickets (Love and Walker 1979, Kevan 1982, Rentz 1994 1996) emphasizing the characteristics of the scales covering their bodies. Undoubtedly, the scales are an autapomorphic character of the Mogoplistidae in Orthoptera. Several previous authors also considered scales to be an apomorphy of the Mogoplistidae and suggested that their shapes could be used to characterize different taxa. Saussure (1877) pointed out that the scale-like setae covering the body surface was particularly characteristic of this family. Chopard (1949) compared the scales to similar structures in Lepidoptera. Desutter-Grandcolas (1998) illustrated mogoplistid scales found on the cerci and stated that scales are diverse and can be used in the phylogenetics of the Mogoplistidae.

Entomologists have described scales in some Apterygota, i.e., the Tomoceridae of Collembola (Greenslade 1994), *Lepidocampa weberi* Oudemans (Diplura: Campodeidae) (Conde and Pages 1994), and the Lepidoplematidae and Machilidae of Thysanura (Smith and Watson 1994, Watson and Smith 1994). Thysanuran insects are typically covered with tiny silver scales from which their common name, silverfish, is derived. However, scales on crickets (Orthoptera) have rarely been reported in the past, and little is known about their structure and function.

Cricket scales may be homologous with those of Lepidoptera and Thysanura and even all Apterygota. The wing scales of Lepidoptera, Trichoptera, some Diptera, i.e., Cecidomyiidae, Psychodidae, and Culicidae (Colless and McAlpine 1994), and some Psocoptera (Smithers 1994) are flattened and striated macrotrichia (Lawrence et al. 1994). From the aspect of morphogenesis, insect scales may originate from setae with a common structure (Snodgrass 1967). However, taxonomists have usually neglected and omitted scale structure when studying scaly crickets (Shiraki 1930, Love and Walker 1979, Yin and Liu 1995).

The present work examines the elaborate structure of scales of mogoplistid crickets in ultra-fine detail. Furthermore, the consistency and variability of scale morphology are analyzed to determine its value as a taxonomic character (Mayr and Ashlock 1991).

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MATERIALS AND METHODS

Examination of scales

Scales of 10 species of Mogoplistidae from Taiwan (Yang and Yen 2001) were used (Table 1). For each species, five specimens were examined in this study. The entire specimen was observed using SEM. Details regarding the SEM method can be found in Yang et al. (1996) with slight modifications.

Scales were sampled from the pronotal disc and the posterior margin of the pronotum, respectively (Fig. 1). When observed under SEM, the scale faces were held parallel to the plane of the photographic image in order to always maintain the angle measurement in the proper aspect. Quantitative characters of a scale produced from different measurements are shown in figure 2. The scale used for measurements was the largest one on the pronotal disc of each species and of both sexes. Nested ANOVA and Duncan's multiple range test, including significance test and posterior test, were used to evaluate characters between different species and between sexes in a single species, but not to examine variation among individuals.

Table 1. Number of scale sizes on the pronotal area among different mogoplistes species

Species from Taiwan	Number of scale sizes
Ornebius formosanus (Shiraki)	7
O. bimaculatus (Shiraki)	5
O. fuscicerci (Shiraki)	5
O. kanetataki (Matsumura)	7
O. fastus Yang and Yen	6
O. infuscatus (Shiraki)	6
Ectatoderus luctisonus Yang and Yen	5
E. annulipedus (Shiraki)	5
Cycloptiloides orientalis Chopard	6
Micrornebius perrarus Yang and Yen	3

Measurement of scales

Measurements include the middle length (mdl), width (wdt), angle of the lateral carina of a scale, and the number of lateral carinae. The angle formed by the middle and lateral carinae, at the widest part of

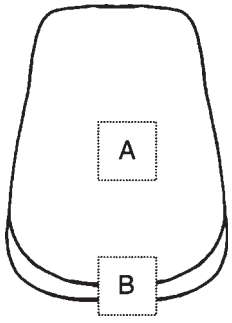

Fig. 1. Pronotum of Mogoplistidae in dorsal view, showing both the disc (A) and posterior margin (B) of the pronotum where scales were sampled for this study.

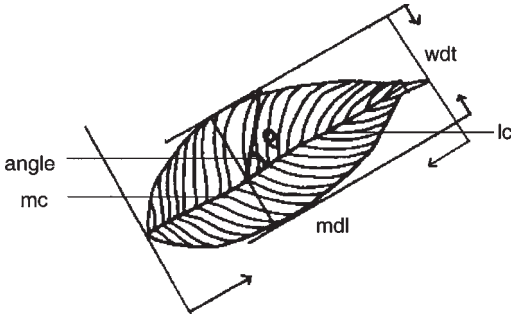

Fig. 2. Measurements of scales of the Mogoplistidae. angle: angle formed by the middle and lateral carinae at the widest part of each scale; lc: lateral carina; mc: middle carina; mdl: middle length; wdt: widest width.

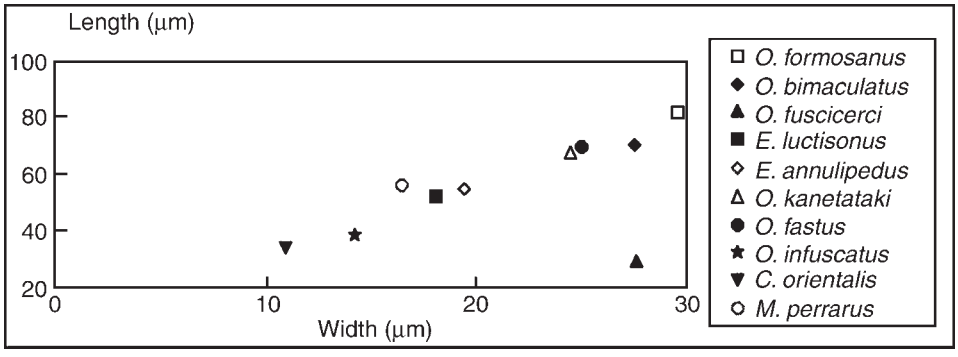

Fig. 3. Scatter graph showing the retionship between widest width and middle length of scales on the pronotal disc of the Mogoplistidae.

each scale, was investigated as a taxonomic character (Fig. 2). In addition, the proportion of the middle length to the widest width, the density of the lateral carinae, and the angle of the lateral carinae were calculated, and these characters are also evaluated as potential taxonomic characters.

RESULTS AND DISCUSSION

General morphology of scales

Each individual scale is broad and leaf-like (Fig. 2), and its middle carina is similar to the midrib of a plant leaf. Lateral carinae originate from the middle carina and are similar to branch veinlets of a leaf. Scales from the disc of the pronotum vary in size. The greater size of a scale implies a longer middle carina and an increased width at the middle of the scale. The relationship between the middle length and the width of a scale is almost linear (Fig. 3). This means that size is an inter-specific difference, but the shape of the scales does not constitute an inter-specific difference in mogoplistids as shown in the results. Three to 7 different sizes of scales were recognized among the species examined from Taiwan (Table 1). Scales on the pronotal disc of the 2

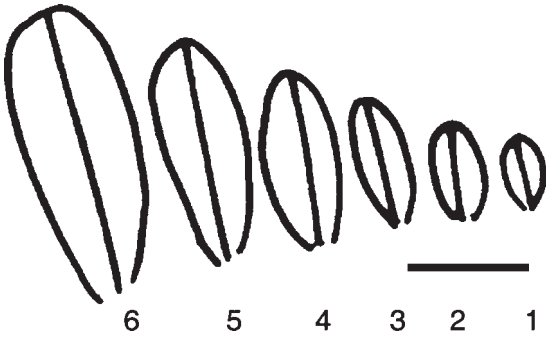

Fig. 4. Scales of the pronotal disc of *Ectatoderus annulipedus* arranged in 6 sizes (bar = 23.07 μm).

Table 2. ANOVA for different characters of pronotal disc scales: (A) the character of proportion of middle length by widest width; (B) density of the lateral carinae; (C) degree of the angle formed by the middle and lateral carinae, among 10 species of Mogoplistidae from Taiwan

A

Source	DF	SS	MS	*F* value	*P*
species	8	8.810	1.101	1.023	n.s.
sexes	9	10.144	1.127	7.564	0.001
individuals	18	2.682	0.149		

B

Source	DF	SS	MS	*F* value	*P*
species	8	12.283	1.535	1.038	n.s.
sexes	9	13.304	1.478	66.223	0.001
individuals	18	0.401	0.022		

C

Source	DF	SS	MS	*F* value	*P*
species	8	4391.555	548.944	20.934	0.001
sexes	9	236.000	26.222	19.961	n.s.
individuals	18	926.000	51.444		

n.s.: non-significant.

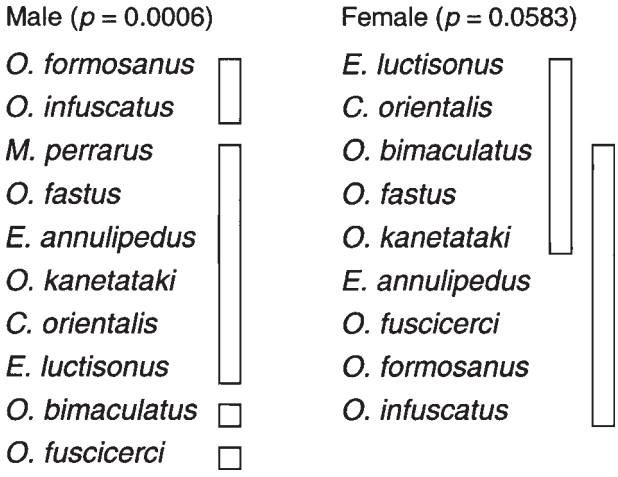

Fig. 5. Duncan's multiple range tests on the character of the proportion of middle length by width of scales on pronotal disc of the Mogoplistidae. *p*: probability of *pr* > *F* when the significance is tested. α: confidence level of Duncan's test (α = 0.05).

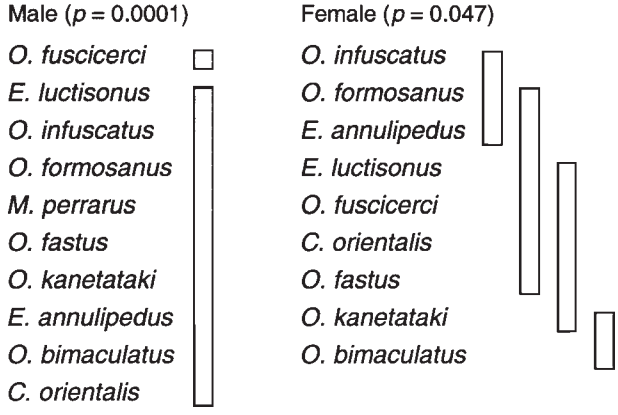

Fig. 6. Duncan's multiple range tests on the character of the density of lateral carinae of scales on pronotal disc of the Mogoplistidae. *p*: probability of *pr* > *F* when the significance is tested. α: confidence level of Duncan's test (α = 0.05).

species, *Ornebius formosanus* (Shiraki) and *Micrornebius perrarus* Yang and Yen, have 3 different sizes, whereas, those of *Ectatoderus annulipedus* (Shiraki) show 6 sizes (Fig. 4).

Scales arise from the cuticle, are directed posteriorly, and are arranged in overlapping layers. The distal end of each scale is free from the cuticle and generally much wider than the basal part. Scale shapes at the posterior margin of the pronotum are easily distinguished into 2 different types in the 10 species in Taiwan (Fig. 9E-F). Scales of the 1st type are elongated with their posterior margin truncate. Scales of the 2nd type are ovate, with the widest part wider than the length of the middle line; its hind margin is distinctly convex. Elongated scales are restricted to the 6 species of the genus *Ornebius* (Fig. 8). The other 4 species of the genera *Ectatoderus*,

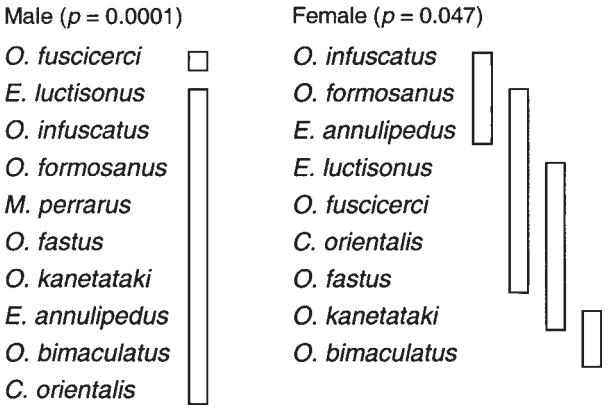

Fig. 7. Duncan's multiple range tests on the character of the angle of the lateral carina of scales on pronotal disc of the Mogoplistidae. *p*: probability of *pr* > *F* when the significance is tested. α: confidence level of Duncan's test (α = 0.05).

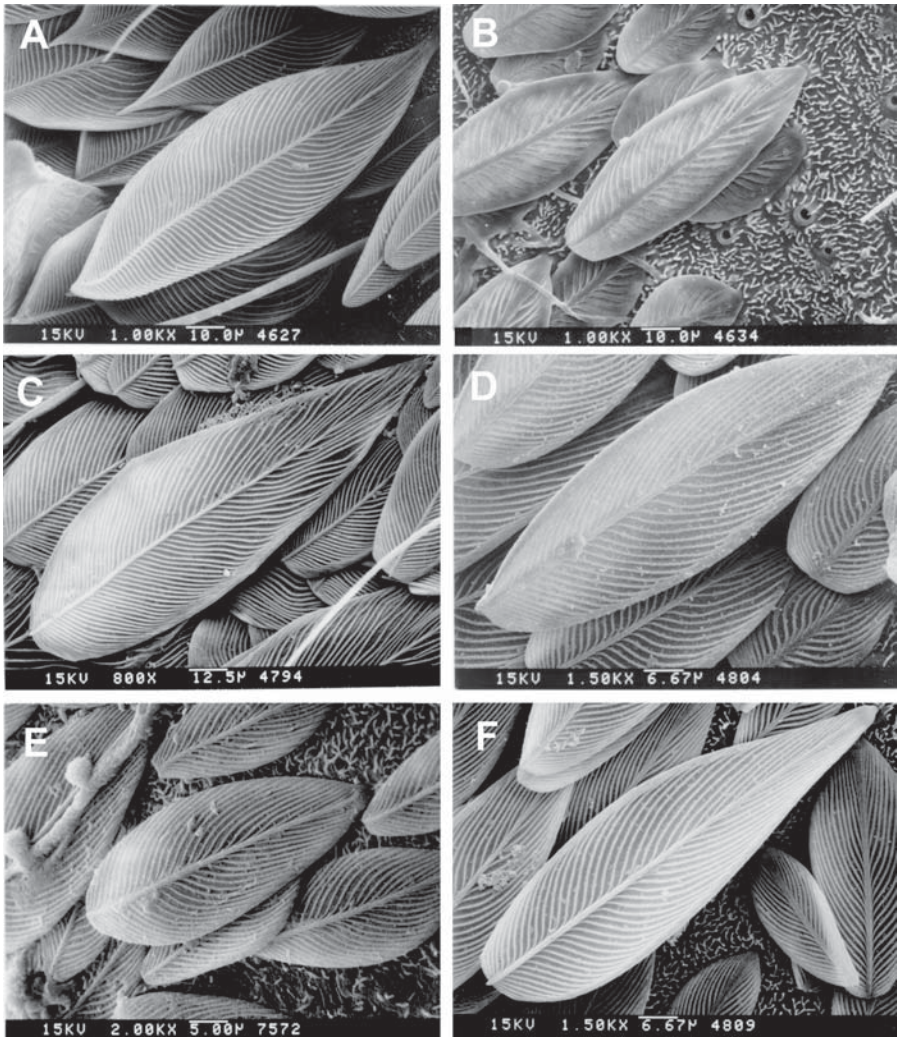

Fig. 8. Scales of the Mogoplistidae on pronotal disc by SEM. A: *Ornebius formosanus*; B: *O. bimaculatus*; C: *O. fuscicerci*; D: *O. kanetataki*; E: *O. infuscatus*; F: *O. fastus*.

Cycloptiloides, and *Micrornebius* have scales of the ovate type (Fig. 9A-D).

Character evaluation

Three characters of both sexes, i.e., the proportion of middle length to widest width (L/W), the density of lateral carinae (no./mm), and the angle of the lateral carina, were tested by Duncan's multiple range test (Table 2 A-C). Based on the proportion of the middle length in relation to the width of the male's scales, and a significance level of $p = 0.0006$, the 10 species from Taiwan were distinguished as 4 groups. The 1st group consisted of only 1 genus with 2 species, *O. formosanus* (Shiraki) and *O. infuscatus* (Shiraki). The 2nd group consisted of 6 species from 3 genera. The others are 2 singletons, i.e., *O. bimaculatus* (Shiraki) and *O. fuscicerci* (Shiraki) (Fig. 5).

The density of the lateral carinae of male scales did not significantly differ at $p = 0.0001$, except in the species, *Ornebius fuscicerci* (Shiraki). In contrast, it significantly differed ($p = 0.047$) from that of female scales. However these species show continuous variation in the grouping of post-tests ($\alpha = 0.05$) (Fig. 6). Group 1 includes 3 species, i.e., *O. infuscatus*, (Shiraki), *O. formosanus* (Shiraki), and *E. annulipedus* (Shiraki), but group 2 has 2 species which overlap with group 1 and 4 species which overlap with group 3. Group 3 has only 1 species, *O. kanetataki* (Matsumura) overlapping with group 4. Only group 1 and group 4 significantly differ. Therefore, the character is not sufficient to distinguish all of the examined species. The angle formed by the middle carina

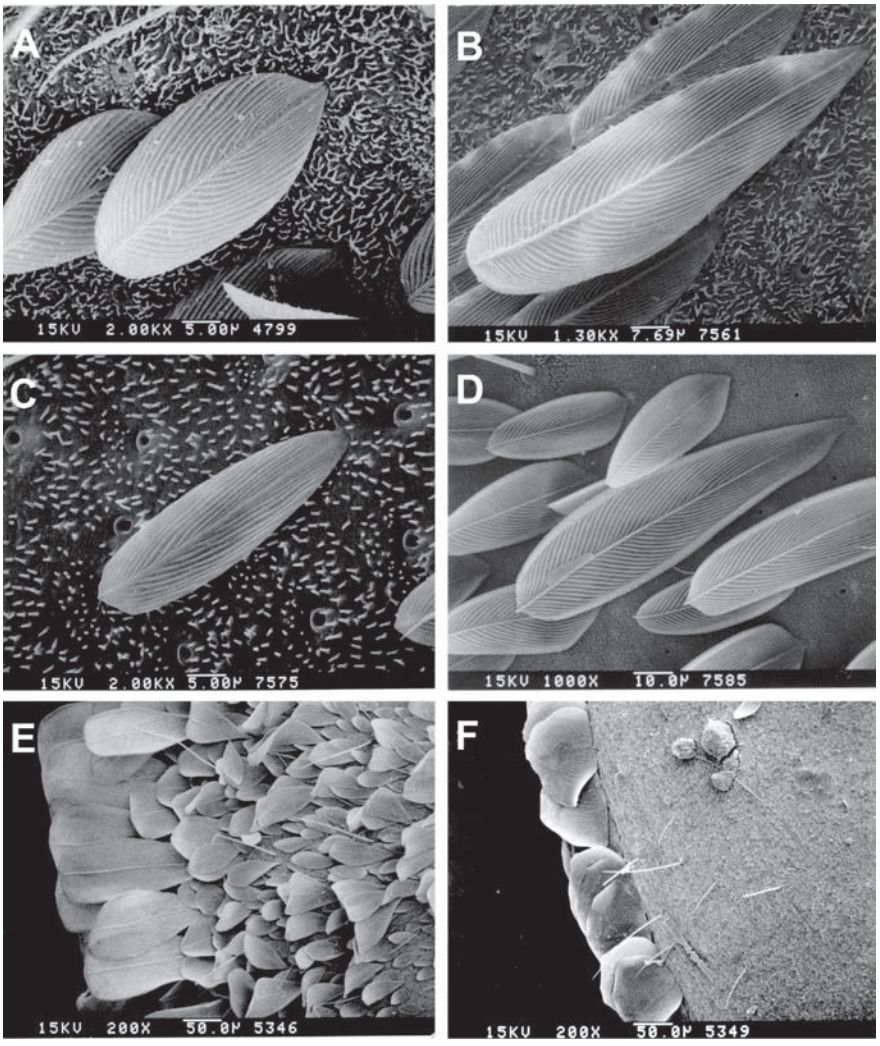

Fig. 9. Scales of the Mogoplistidae on pronotal disc (A-D) and posterior margin (E-F) by SEM. A: *Ectatoderus luctisonus*; B: *E. annulipedus*; C: *Cycloptiloides orientalis*; D: *Micrornebius perrarus*; E: *Ornebius fuscicerci*; F: *E. luctisonus*.

and each lateral carina did not significantly differ for females at $p = 0.0118$, or for males ($p = 0.0045$) (Fig. 7).

Results of the proportion and angle in females were not clearly significant between species (Figs. 5-7). In general, females of the 10 species could not be clearly distinguished using the 3 morphometric characters. Therefore, the male scales were mainly used for tests in the present study. In taxonomic studies, the characters from the male can be used for specific and generic definitions and can serve as identification characters. The male genitalia and the acoustics are the most common characters used in crickets (Liu et al. 1998). Male scales can be useful as a taxonomic character to taxonomists as well when they study this family. Although scales do not significantly differ between species, the peculiar structure of scales in this family is worth considering as background knowledge for species definitions.

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REFERENCES

Chopard H. 1949. Order des Orthopteres. *In* PP Grassè, ed. Traitè de Zoologie. Vol. 9. Paris: Masson, pp. 617-722.

Colless DH, DK McAlpine. 1994. Diptera (Flies). *In* ID Naumann, ed. Systematic and applied entomology, an introduction. Melbourne Univ. Press, pp. 374-405.

Conde B, J Pages. 1994. Diptera. *In* ID Naumann, ed. Systematic and applied entomology, an introduction. Melbourne Univ. Press, pp. 269-271.

Desutter-Grandcolas L. 1998. Comparative morphology of cercal structures in true crickets and their allies (Orthoptera, Ensifera): a phylogenetic aspective. Zoomorphology **118:** 235-243.

Greenslade PJM. 1994. Collembola. *In* ID Naumann, ed. Systematic and applied entomology, an introduction. Melbourne Univ. Press, pp. 252-264.

Jin XB. 1996. Rearing and enjoyment of common singing insects. Shanghai: Shanghai Scientific and Technological Literature Publishing House. 157 pp. (in Chinese)

Kevan DK. McE. 1982. Orthoptera. *In* SP Parker, ed. Synopsis and classification. Vol. 2. New York: McGraw Hill, pp. 352-379.

Lawrence JF, ES Nielsen, IM Mackerras. 1994. Skeletal anatomy. *In* ID Naumann, ed. Systematic and applied entomology, an introduction. Melbourne Univ. Press, pp. 3-24.

Liu SH, JT Yang, HK Mok, CT Yang. 1998. Acoustics and taxonomy of Nemobiidae (Orthoptera) from Taiwan. J. Taiwan Mus. **51:** 55-124.

Love RE, TJ Walker. 1979. Systematics and acoustic behavior of scaly crickets (Orthoptera: Gryllidae: Mogoplistinae) of Eastern United States. Trans. Am. Entomol. Soc. **105:** 1-66.

Mayr E, D Ashlock. 1991. Principles of systematic zoology. New York: McGraw-Hill. 475 pp.

Rentz DCF. 1994. Orthoptera. *In* ID Naumann, ed. Systematic and applied entomology, an introduction. Melbourne Univ. Press, pp. 369-393.

Rentz DCF. 1996. Grasshopper country, the abundant orthopteroid insects of Australia. Sydney: Univ. of New South Wales Press. 284 pp.

Saussure H. 1877. Mélanges orthopterologigues. Vime fascicale. III Gryllides. Mem. Soc. Phys. Hist. Nat. Geneve **25:** 1-344.

Shiraki T. 1930. Orthoptera of the Japanese Empire. Part I. (Gryllotalpidae and Gryllidae). Insecta Matsumurana **4:** 181-252.

Smith GB, JAL Watson. 1994. Thysanura. *In* ID Naumann, ed. Systematic and applied entomology, an introduction. Melbourne Univ. Press, pp. 275-277.

Smithers CN. 1994. Psocoptera. *In* ID Naumann, ed. Systematic and applied entomology, an introduction. Melbourne Univ. Press, pp. 308-311.

Snodgrass RE. 1967. Principle of insect morphology. New York: McGraw-Hill. 667 pp.

Watson JAL, GB Smith. 1994. Arachaeognatha. *In* ID Naumann, ed. Systematic and applied entomology, an introduction. Melbourne Univ. Press, pp. 272-274.

Yang JT, FS Yen. 2001. Mogoplistidae (Orthoptera: Gryllidae) of Taiwan with lectotype designations of Shiraki's species. Orient. Insects **35:** (Accepted).

Yang SY, JT Yang, MY Chen. 1996. Insect-induced galls of *Machilus zuihoensis* Hay. var. *zuihoensis* in Guandaushi Forest. Ann. Taiwan Mus. **39:** 17-29. (in Chinese)

Yin HS, XW Liu. 1995. Synopsis on the classification of Grylloidea and Gryllotalpoidea from China. Shanghai: Shanghai Scientific and Technological Literature Publishing House. 237 pp. (in Chinese with English keys)

鉦蟋蟀(直翅目：蟋蟀總科：鉦蟋蟀科)鱗片形態學及特徵評估

楊正澤　顏汎昇

本研究利用掃描式電子顯微鏡全面探討 10 種臺灣鉦蟋蟀科之前胸背板中央區及後緣鱗片的奇特構造。並首度以掃描式電子顯微鏡照片為基礎，描述鉦蟋蟀科鱗片的一般特性和量化特徵，並提供各種之超微構造圖。除此之外，鱗片構造應用於鉦蟋蟀科分類時，應用為形態學特徵之可行性，亦利用鄧肯氏多變方分析加以評估，結果顯示雄性之鱗片構造較為理想又能配合其他分類特徵同時應用。

關鍵詞：鉦蟋蟀科，掃描式電子顯微照相，鱗片，臺灣，超微構造。

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