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A review of the snakefly genus *Sininocellia* (Raphidioptera, Inocelliidae): discovery of the first male and description of a new species from China

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Abstract

The snakefly genus *Sininocellia* is one of the most enigmatic groups in Inocelliidae, with an obscure phylogenetic status due to lack of male adults. A newly discovered male adult of *Sininocellia gigantos* Yang is described, representing the first male of this genus. Additionally, a new species, *Sininocellia chikun* sp. n., is described based on two females from central China. The phylogenetic relationships between *Sininocellia* and other relatives as well as the biogeography are discussed.

Introduction

In 1985, Chikun Yang described a spectacular new snakefly of the family Inocelliidae based on two female specimens from the Wuyishan mountains in the province of Fujian in the southeast of China. With a forewing length just over 21 mm, the beautiful yellowish-brown insect with transparent iridescent wings was (and still is) the largest known extant snakefly. The new species could not be assigned to any of the described genera, and therefore Chikun Yang erected a new genus; the conspicuous insect found its way into the scientific literature under the name *Sininocellia gigantos* (Yang 1985).

In a monograph of the Raphidioptera of the world (Aspöck et al. 1991) only a German translation of the Chinese description (with a few comments) could be presented, but several years later the female paratype could be re-examined and re-described. In a subsequent paper (U. Aspöck & H. Aspöck 1999), drawings of head, wings and particularly the female genital segments were presented, and the systematic position of the species and genus *Sininocellia* Yang was discussed.

Despite significant characters of the female genitalia no consensus on the systematic position could be achieved. The fact that the Media anterior vein in the hind wing of *S. gigantos* forms a longitudinal vein demonstrated a conspicuous similarity with *Fibla* Navás (in all other genera of extant Inocelliidae this vein is a cross-vein; see, however, discussion); nonetheless, this character is probably a plesiomorphic state. Thus, an assessment of the systematic position of *Sininocellia* was postponed at least until a male would be available for study. In the following years no further material of *Sininocellia* emerged, but recently a few specimens (including a male) of *Sininocellia* belonging to two species – *S. gigantos* and a new species – became available so that a comprehensive revision of this enigmatic genus of Inocelliidae can now be performed.

Material and methods

Specimens for the present study are deposited in the Entomological Museum of China Agricultural University (CAU), Beijing. Preparations of the genital segments were made by clearing the apex of the abdomen in a cold, saturated KOH solution for 6–8 h. After rinsing

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the KOH with acetic acid and water, the apex of the abdomen was transferred to glycerine for further dissection and examination. The terminology of the genitalia generally follows that of Aspöck et al. (1991) and U. Aspöck & H. Aspöck (2008).

Taxonomy

Genus *Sininocellia* Yang, 1985

Sininocellia Yang, 1985: 25. Type species *Sininocellia gigantos* Yang 1985: 26 (original designation); Aspöck et al. 1991 (monograph, translation of original description); U. Aspöck & H. Aspöck 1999 (morphology).

Diagnosis. Snakeflies of large body size. Body coloration of adult generally blackish brown with complicate brownish or yellowish markings on head, thorax, and abdomen. Wings transparent, with bases yellow, and medially with a small pale yellowish marking on subcostal region. A crossvein present between anterior and posterior branch of Rs, forming a closed cell; MA in hindwing present as a long vein obliquely connecting Rs and MP. Male abdominal segments 8–9 strongly inflated. Male gonocoxite 9 shell-like, slightly longer than tergite 9, and nearly as long as wide; inner surface dorsally with a feebly prominent stylus, which bears numerous bristles. Pseudostylus (gonapophysis 9) feebly sclerotized, arcuate and extremely narrow. Fused parameres (complex of amalgamated gonocoxites, gonapophyses, gonostyli 10) flattened proximally, with a slender and hoe-shaped distal process. Gonarcus (fused gonocoxites 11) shield-like and strongly sclerotized, medially with slender projections. A strongly sclerotized plate present on proximodorsal portion of endophallus which is homologized with the serratulum of *Fibla* and *Negha*. Female sternite 7 posteriorly emarginate; tergite 8 slightly extended ventrad, covering subgenital plate in lateral view; subgenital plate membranous, with grooved region. Atrium bursae with a disc-shaped plate, which is strongly sclerotized or membranous.

Distribution. This genus is endemic to China and mainly distributed in several mountains of central and southeastern China.

Sininocellia gigantos Yang

Figures 1–2, 4–5, 7–17, 20

Sininocellia gigantos Yang, 1985: 26 (original description); U. Aspöck & H. Aspöck, 1999 (re-description, illustrations of head, wings, and female genitalia). Type locality: China (Fujian).

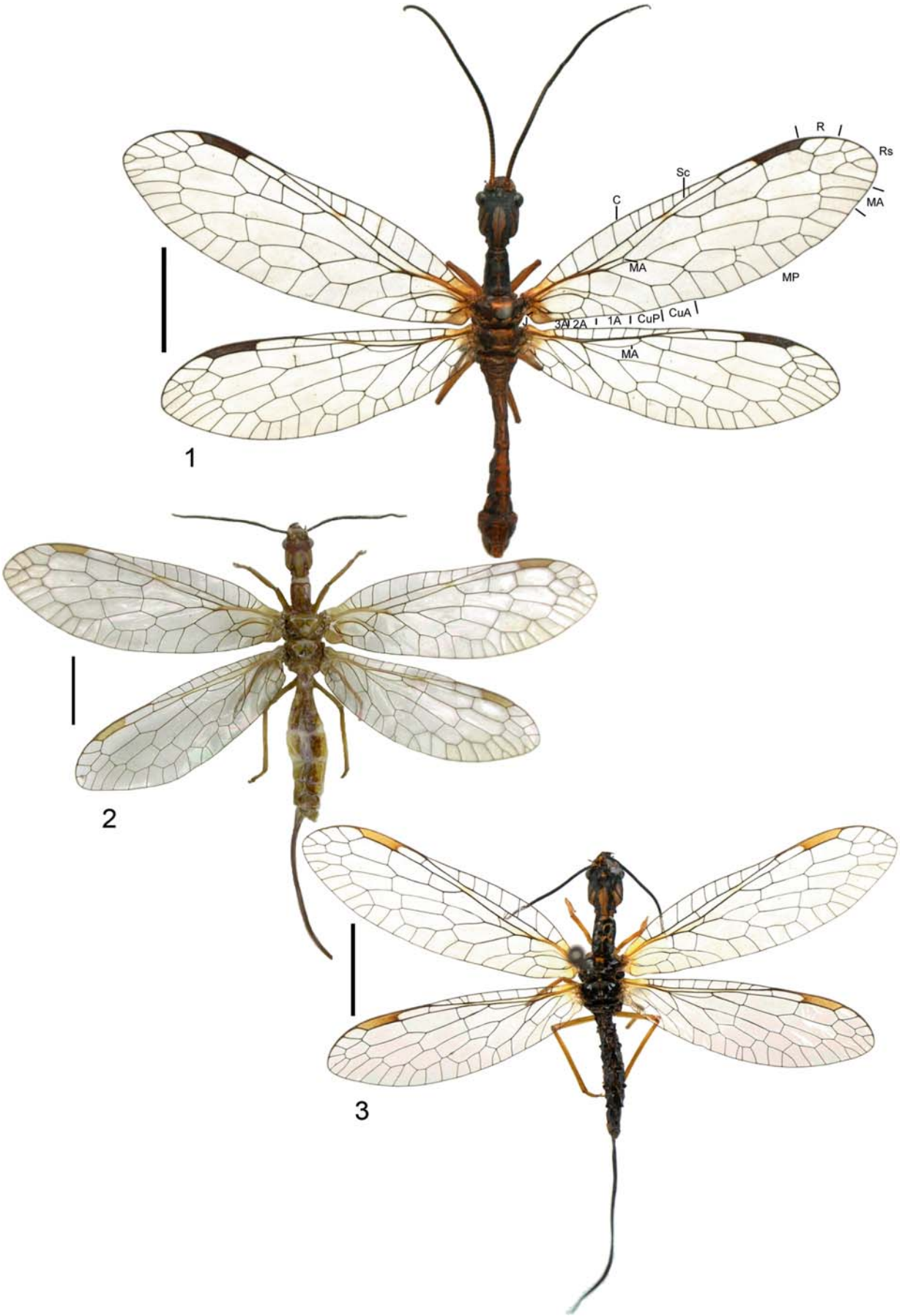
Diagnosis. Head and pronotum blackish brown with complicate patterns of yellow markings. Abdomen yellow, with reddish brown longitudinal stripes, forming a zigzag pattern. Male gonocoxite 9 shell-like, nearly as long as wide, with a broad but feebly prominent stylus on inner side. Gonarcus shield-like, medially with a pair of spinous projections. Paramere distally with a hoe-shaped projection. Endophallus proximally with a strongly sclerotized plate (serratulum) on dorsal surface. Female atrium bursae with a strongly sclerotized plate.

Description. Male. Body length 17.5 mm; forewing length 16.8 mm, hindwing length 14.5 mm.

Head (Figs 1, 4) nearly rectangular, slightly widened posteriorly, blackish brown with clypeus yellow; frons with a small yellow spot; vertex with four pairs of yellow markings, which differ in shape, lateral three pairs are respectively subtriangular, band-like and small ovoid; median pair elongated, extending to occiput; ventral part laterally with large yellow markings, which bear reticulate black lines. Occiput also with a pair of lateral yellow markings. Antennal sclerite (torulus), scape, pedicel, and proximal four segments of flagellum yellowish brown, remaining segments of flagellum blackish brown. Mouthparts yellow, with labrum, distal half of mandibles, maxillary and labial palpi dark brown.

Thorax yellow; pronotum (Figs 1, 4) black, with lateral margins yellow, and medially with yellow stripes, forming a heart-shaped pattern; meso- and metanotum laterally with a pair of broad reddish brown markings. Legs pale yellowish brown, with yellowish setae. Wings (Fig. 1) transparent, with bases yellow, and each with a yellowish marking on subcostal region; pterostigma blackish brown; veins blackish brown. Rs terminally with 4–6 branches.

Abdomen (Fig. 4) yellow, with reddish brown longitudinal stripes, forming a zigzag pattern in dorsal view. Abdominal segments 8–9 strongly inflated. Tergite 9 (Figs 7, 9) approximately 1.5 times as long as sternite 9, anterior margin feebly incised medially, posterior margin truncate. Sternite 9 (Figs 7, 10) arcuate, with anterior margin distinctly prominent. Gonocoxite 9 (Figs 7–8) broadly shell-like, slightly longer than tergite 9, and nearly as long as wide; distal margin with thickened edge and a few bristles; stylus (gonostylus 9) present dorsomedially on inner side, rather broad but feebly prominent, with numerous bristles, which are directed ventrad. Pseudostyli (gonapophyses 9) (Figs 8, 10) paired, feebly sclerotized, extremely narrow and arcuate. Fused parameres (complex of fused gonocoxites, gonapophyses, gonostyli 10) (Figs 8, 14) flatly trapezoidal on proximal portion in dorsal view, anterior margin concaved and much more sclerotized than remaining part, distal portion ventrally protruding into a slender projection, which is hoe-shaped on apex. Gonarcus (fused gonocoxites 11) (Figs 8, 12–13) shield-like in caudal view, median portion posteriorly protruding into a pair of spinous projections with tip slightly curved dorsad, ventral portion with a pair of roundly produced projections. Endophallus (Figs 8, 10) short, laterally with numerous bristles. A strongly sclerotized plate (serratulum) (Figs 8, 15) present on dorsal surface of base of endophallus, nearly campaniform, dorsally with a projection, which is anteriorly protruding and concaved at tip. Ectoproct (Figs 7, 9) in lateral view



Figures 1–3. Habitus images of *Sininocellia* spp. **1.** *S. gigantos* Yang, male from Guangdong Province, China; **2.** same, holotype female from Fujian Province, China; **3.** *S. chikun* sp. n., holotype female from Shaanxi Province, China.

Figures 4–6. Living adults of *Sininocellia* spp. **4.** *S. gigantos* Yang, male from Guangdong Province, China (photographer: Chenghui Zhan); **5.** same, female from Guangdong Province, China (photographer: Chenghui Zhan); **6.** *S. chikun* sp. n., female from Shaanxi Province, China (photographer: Xiaoguang Zheng).

subtriangular with round apex. Hypandrium internum (Fig. 10) small, with lateral lobes narrowly foliate.

Female. Body length 17.0–22.1 mm (without ovipositor)/29.0–35.0 mm (with ovipositor); forewing length 17.0–23.3 mm, hindwing length 15.0–20.6 mm.

Body colour and marking patterns similar to male (Figs 2, 5), but with pterostigma yellowish brown.

Sternite 7 (Fig. 16) subtrapezoidal in lateral view, with convex posterior margin in ventral view. Tergite 8 (Fig. 16) nearly rectangular, extending ventrad in lateral view. Subgenital plate (fused gonocoxites 8) (Figs 16–17) membranous with grooved surface, covered by tergite 8 in lateral view. Bursa copulatrix (Fig. 16) much longer than abdominal segments 7 + 8; atrium bursae subquadrate, encapsulating a strongly sclerotized and disc-shaped plate; sacculus bursae strongly inflated, receptaculum seminis short and narrowed, with a pair of tubular glandulae distad.

Type material. Holotype ♀ [pinned], "CHINA: Fujian Prov., Jianyang, Aotou [27°40′ N, 117°40′ E, ~1040 m], 13.vi.1981, Shicheng Qi" (CAU). Paratype 1♀ [pinned], "CHINA: Fujian Prov., Wuyishan, Xianfengling [27°43′ N, 117°38′ E, ~1200 m], 25.vi.1980, Yunwei Li & Wenfeng Cheng" (CAU).

Other material. 1♂ [pinned], CHINA: Guangdong Prov., Ruyuan, Nanling National Nature Reserve, Wulikeng [24°55′ N, 113°05′ E, 600 m], 5.vi.2009, Chenghui Zhan (CAU); 1♀ [pinned], CHINA: Guangdong Prov., Ruyuan, Nanling National Nature Reserve, Wulikeng, 30.iv.2003, Chenghui Zhan (CAU).

Distribution. This species is recorded in only two isolated mountains in southeastern China (Fig. 20), i.e. Mt. Wuyishan and Mt. Nanling, both of which are famous national nature reserves with rich biodiversity. However, *S. gigantos* may be found in other well preserved mountainous areas close to these two mountains.

Remarks. *Sininocellia gigantos* is known to be the largest species in Inocelliidae. Based on the collecting label data, the adults of this species were found from late April to late June, and the elevation of the collecting sites ranged from 600 to 1200 meters. See remarks under *S. chikun* for the interspecific comparison.

Sininocellia chikun sp. n.

Figures 3, 6, 18–20

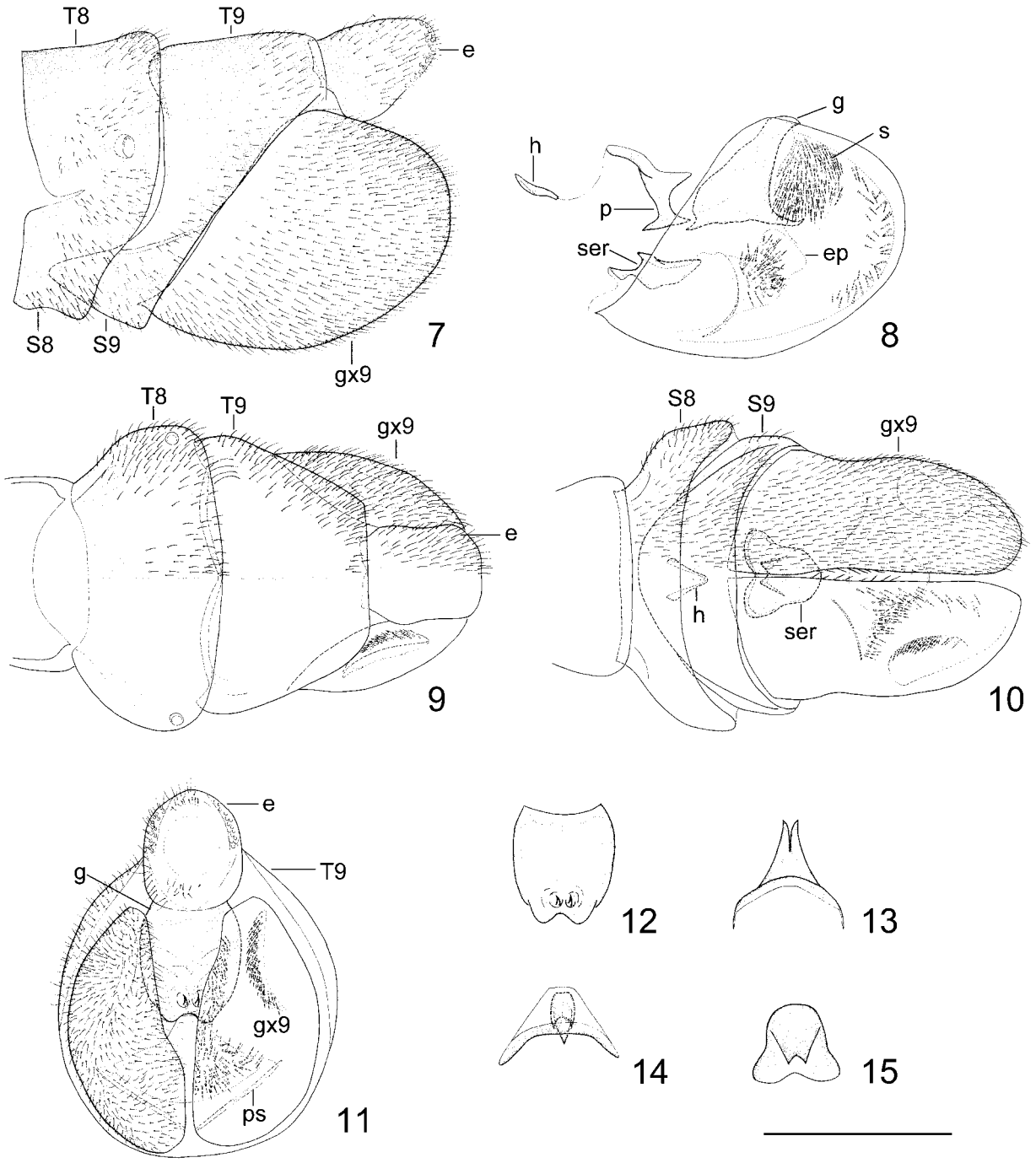
Diagnosis. Head and pronotum blackish brown with complicate patterns of yellow markings. Abdomen reddish brown dorsally, with a yellowish median vitta across each tergite. Female atrium bursae with a membranous plate.

Description. Female. Body length 16.7–20.0 mm (without ovipositor)/28.7–32.0 (with ovipositor); forewing length 17.7–18.0 mm, hindwing length 15.0–15.1 mm.

Head (Figs 3, 6) nearly rectangular, slightly widened posteriorly, blackish brown; clypeus brown, with anterior portion yellow; frons with a small yellow spot; vertex with four pairs of yellow markings, which differ in shape, lateral three pairs are respectively subtriangular, band-like, and small ovoid, median pair elongated, extending to occiput; ventral part laterally with large yellow markings, which bear reticulate black lines. Occiput also with a pair of lateral yellow markings. Antennal sclerite (torulus), scape, and pedicel yellowish brown; flagellum blackish brown. Mouthparts reddish brown.

Thorax (Figs 3, 6) blackish brown; pronotum black, with lateral margins yellow, and medially with yellow stripes, forming a heart-shaped pattern; meso- and metanota black, anteriorly with a small yellow marking at middle. Legs yellow, with yellowish setae. Wings (Fig. 3) transparent, with bases yellow, and each with a yellowish marking on subcostal region; pterostigma yellowish brown; veins blackish brown. Rs terminally with 4–5 branches.

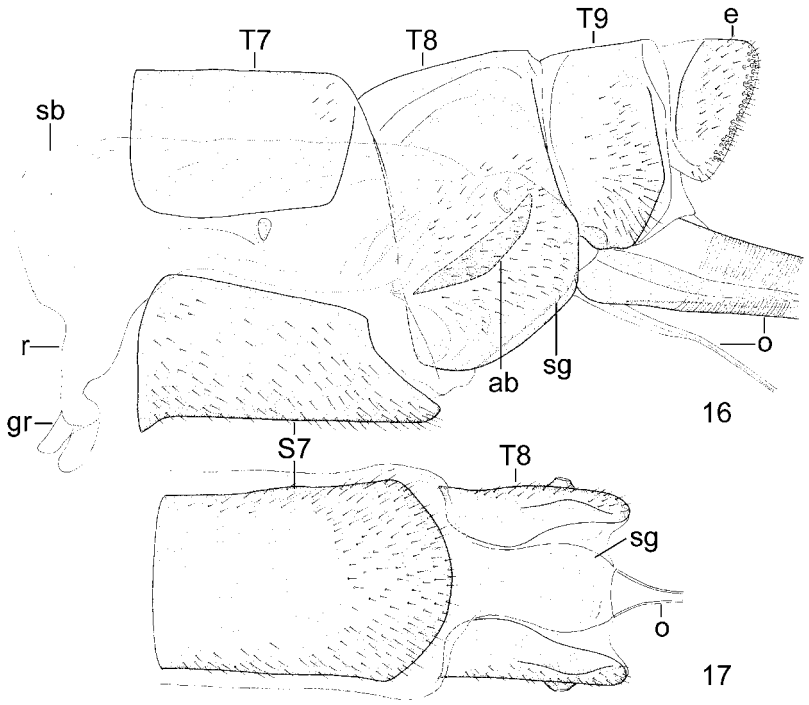
Abdomen (Figs 3, 6) reddish brown dorsally, but pale yellow ventrally, medially with a distinct yellowish vitta



Figures 7–15. Male genitalia of *Sininocellia gigantos* Yang. **7.** Genital segments, lateral view; **8.** Gonocoxite 9 and internal structures, lateral view; **9.** Genital segments, dorsal view; **10.** Genital segments, ventral view; **11.** Genital segments, caudal view; **12.** Gonarcus (= fused gonocoxites 11), caudal view; **13.** Gonarcus, dorsal view; **14.** Fused parameres (= gonocoxites-gonapophyses-gonostyli complex 10), dorsal view. **15.** Serratulum, dorsal view. Abbreviations: **e** – ectoproct; **ep** – endophallus; **g** – gonarcus; **gx9** – gonocoxite 9; **h** – hypandriun internum; **p** – fused parameres (complex of fused gonocoxites, gonapophyses, and gonostyli 10); **ps** – pseudostyli (= gonapophyses 9); **s** – gonostylus 9; **S** – sternum; **ser** – serratulum; **T** – tergum.

across each tergite, and each tergite of pregenital segments with pair of small yellowish spots on posterior margin. Sternite 7 (Figs 18–19) subtrapezoidal in lateral view, with convex posterior margin in ventral view. Tergite 8 (Fig. 18) extending ventrad in lateral view, with arcuate anterior margin and slightly prominent posteroventral corner. Subgenital plate (fused gonocoxites 8) (Fig. 19) membranous with grooved surface, covered by tergite 8 in lateral view. Bursa copulatrix (Fig. 18) nearly as long as abdominal segments 7 + 8; atrium bursae inconspicuous, encapsulating a membranous plate; sacculus bursae strongly inflated, receptaculum seminis strongly narrowed, nearly as long as sacculus bursae, with a pair of tubular glandulae distad.

Male. Unknown.



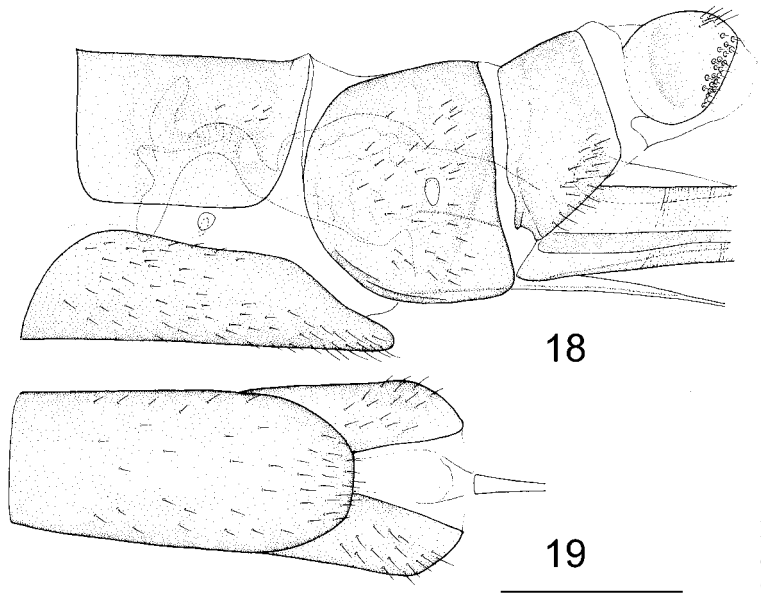
Figures 16–17. Female genitalia of *Sininocellia gigantos* Yang. **16.** Genital segments, lateral view; **17.** Genital segments, ventral view. Abbreviations: **ab** – atrium bursae; **e** – ectoproct; **gr** – glandula receptaculi; **o** – ovipositor; **r** – receptaculum seminis; **S** – sternum; **sb** – sacculus bursae; **sg** – subgenitale; **T** – tergum.

Type material. Holotype ♀ [pinned], "CHINA: Shaanxi Prov., Ningshan, Sanguanmiao [33°24′ N, 108°17′ E, 1236 m], 10.vi.2010, Xiaoguang Zheng" (CAU). Paratype 1♀ [preserved in alcohol], "CHINA: Henan Prov., Luchuan, Longyuwan, Tingtaoju [33°42′ N, 111°46′ E], 1000 m, 20.v.2008, Weihai Li" (CAU).

Etymology. The new species is dedicated to late Prof. Chikun Yang, who established the genus *Sininocellia* and made significant contributions to the taxonomy of Chinese Raphidioptera. The name is an indeclinable noun in the nominative being an apposition to the name of the genus.

Distribution. The new species occurs in two localities of the Qinling Mountain Range (Fig. 20), which is considered as a boundary between the Palaearctic and Oriental fauna in China.

Remarks. Although the male is still unknown, the species can also be distinguished from *S. gigantos* in the female by the abdomen, which is dorsally reddish brown with a narrow yellowish median vitta, and by the absence of sclerotized plate in the atrium bursae. In *S. gigantos* the abdomen is generally yellow, dorsally with a pair of reddish brown stripes, which form zigzag pattern, and the atrium bursae possesses a strongly sclerotized plate. Based on the collecting label data, the adults of the new species were found from late May to early June, and the elevation of the collecting sites ranged from 1000 to 1300 meters.



Figures 18–19. Female genitalia of *Sininocellia chikun* sp. n. **18.** Genital segments, lateral view; **19.** Genital segments, ventral view.

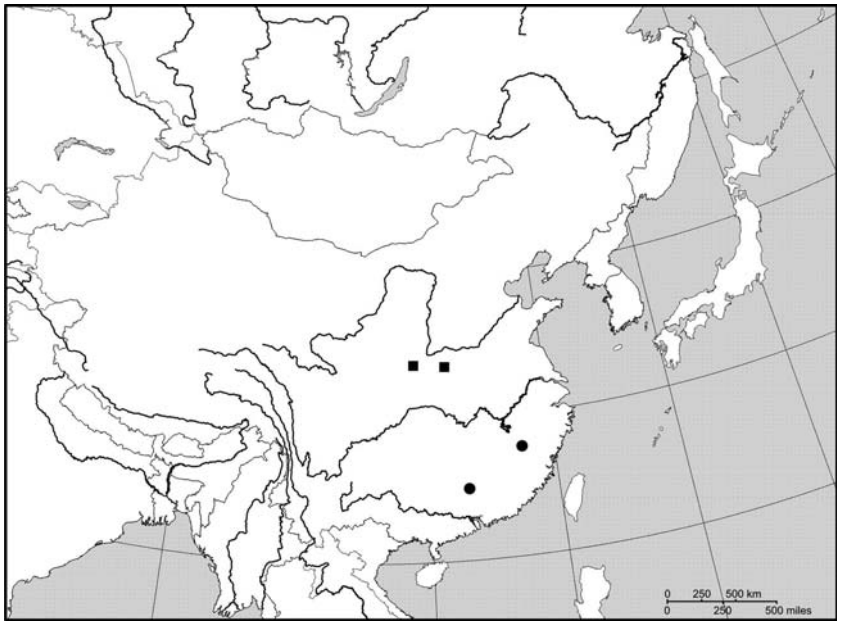


Figure 20. Geographic distributions of *Sininocellia* spp. ● *S. gigantos* Yang; ■ *S. chikun* sp. n.

Discussion

Phylogenetic considerations

Six parameters of *Sininocellia* that have possible phylogenetic relevance to other inocelliid genera will be addressed in the following:

1) The size: The *prima vista* impression of *Sininocellia* is its enormous size. The phylogenetic power of this character must be considered with respect to the enormous variability of size in both sexes known from other species (e.g. *Inocellia crassicornis* (Schummel)). Up to now altogether 6 specimens – 1 male and 5 females of *Sininocellia* are known, so there is no data regarding the variability of the size. Apart from *S. gigantos* the largest species of Inocelliidae is the Nearctic *Negha inflata* (Hagen) with a forewing length of 18.5 mm in the female. Within Raphidiidae the largest species is the Nearctic *Agulla bractea* (Carpenter) with a forewing length of 13.5–16.8 mm in the male and 15–18 mm in the female! All other species of the genus *Agulla* Navás are of smaller size.

2) The longitudinal MA in the hind wing: The longitudinal MA in the hind wing of *Sininocellia* is shared with the Mediterranean inocelliid genus *Fibla* Navás. This vein has been discussed on several occasions, but especially in the treatment of *S. gigantos* in the monograph by Aspöck et al. (1991), and in the context of the redescription of *S. gigantos* based on the female paratype (U. Aspöck & H. Aspöck 1999). All other inocelliid genera lack this longitudinal MA. Whether this is a synapomorphy or a multiple phenomenon remains to be clarified. It is noteworthy that in *Fibla peyerimhoffi* (Navás) this longitudinal MA in the hind wing is reduced to a very short vein, and in several specimens it is partly amalgamated with R (Aspöck et al. 1991, figs 47–49) or even lost. This demonstrates how the loss of MA in the other inocelliid genera could have happened – as an amalgamation with R. In the family Raphidiidae the MA in the hind wing is known as a longitudinal vein or as cross vein, or as an intermediate short oblique vein. The cross vein certainly evolved several times independently by amalgamation of the basal parts with the Media.

The longitudinal MA in the hind wing has been discussed previously as a plesiomorphic condition. More recently this hypothesis was corroborated by the discovery of *Succinofibla aperta* U. Aspöck & H. Aspöck, 2004, an extinct inocelliid from the Eocene Baltic amber with a longitudinal MA in the hind wing. In summary, it may be stated that the longitudinal MA in the hind wing is apparently a symplesiomorphy of *Fibla* and *Sininocellia*.

3) The colourful patterned habitus: This is really an impressive joint character of *Fibla* and *Sininocellia* but there are no arguments which interpret this appearance as a synapomorphy or a symplesiomorphy. *Inocellia fulvostigmata* and *Agulla bractea* may be mentioned as examples of exceptionally coloured species compared to other congeneric species, although they are less spectacular than *Fibla* and *Sininocellia*.

4) Inflated male segments 8 and 9: The inflated male segments 8 and 9 of *S. gigantos* are very impressive; however, we do not know if this is a generic character, since the male of *S. chikun* sp. n. is unknown. The phenomenon of monstrous terminalia is also known from some (but not all) species of the raphidiid genus *Subilla* Navás, however, the concerned species are of normal size, only the genital sclerites, comprising the terminalia inclusively segment 9 (but not segment 8) are enlarged. Thus in the case of *Subilla* the phenomenon is clearly intrageneric.

5) The serratulum: The serratulum is a tiny paired or unpaired sclerite covered by little teeth proximally at the base of the endophallus in *Fibla* and the Nearctic *Negha*. Previously this was discussed as either being an accessory sclerite or a highly reduced sclerite of unknown origin. *Sininocellia gigantos* is equipped with a strongly

sclerotized smooth plate in the position of the serratulum. We interpret this sclerite as being homologous with the serratulum. The serratulum could be a synapomorphy of *Negha*, *Fibla* and *Sininocellia*, even if it represents an archaic sclerite, which has, however, apparently been transformed to the present reduced state.

6) The gonapophyses 9: The gonapophyses 9 of *S. gigantos* are extremely narrow, but this is a trivial autapomorphy. Generally they are feebly sclerotized and foliate in all but two genera. In *Parainocellia* and *Amurinocellia* the gonapophyses 9 (pseudostyli) are hook-like. These sclerites are homologous to the hypovalva of the Raphidiidae and thus belong to the ground pattern of Raphidioptera. However, in our recent study on *Amurinocellia* (Liu et al. 2009a) we interpret them as a secondary derivation of sclerites which already were lost in the stem species of Inocelliidae and thus serve as a synapomorphy of *Parainocellia* + *Amurinocellia.* The foliate gonapophyses 9 of all other genera represent only the basal remnants of the former rod like gonapophyses and belong to the ground pattern of Inocelliidae.

In summary, despite the conspicuous diagnostic characters of *Sininocellia* we have not been successful in revealing any synapomorphy of *Sininocellia* with any other genus of Inocelliidae – except perhaps for the serratulum (see above).

Biogeographic considerations

With respect to the intensive entomological fieldwork carried out in many parts of China in past and particularly in recent years it is peculiar and surprising that such spectacular insects as the *Sininocellia* species have only been found with altogether six specimens. This leads to the conclusion that species of this genus are not only rare, but must have very restricted, small distribution areas. It is a reasonable assumption that both species of *Sininocellia* are restricted to small (and vicariant) areas in central and southeastern parts of continental China, roughly identical with the glacial refugial areas, and that presently they are confined to higher altitudes.

Following the biogeographical concept of De Lattin (1967), *Sininocellia gigantos* can be classified as a monocentric Sinopacific, and *S. chikun* as a monocentric Sinotibetan faunal element, both characterised by a very low expansivity. These two refuge centres are attributed to the Palaearctic, but in reality they are situated in the Oriental realms (Zhang 1999), which is also corroborated by other authors (e.g. Heiser & Schmitt 2012). It is, however, a matter of fact that the higher altitudes in the east and southeast of Asia harbour a considerably high percentage of Palaearctic faunal elements so that these regions can justifiably and convincingly be classified as transitional zones between the Palaearctic and Oriental realm.

The other two genera of Inocelliidae which are represented in China – *Inocellia* Schneider and *Amurinocellia* H. Aspöck & U. Aspöck, both with several species (Liu et al. 2009a, b; Liu et al. 2010a, b) – show a considerably large range of distribution comprising large parts of the western and eastern Palaearctic including transitional areas to the Oriental region (*Inocellia*) and (at least) Siberia and the Korean peninsula (*Amurinocellia*).

However, the route of colonisation taken by *Sininocellia* into southeast China remains entirely unanswered – at least as long as we do not know the sister-group. Even if it can be corroborated that *Fibla* is the sister-group of *Sininocellia*, the explanation of the genesis of this geographic vicariance could not be presented. These phylogenetic and biogeographical questions must be left to a morphological as well as a molecular systematic analysis on the phylogeny of the genera of Inocelliidae.

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