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First record and redescription of *Macandrewella cochinensis* Gopalakrishnan, 1973 (Copepoda, Scolecitrichidae) from the Red Sea, with notes on swarm formation

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Abstract

During a study of the epipelagic zooplankton carried out near the fringing reef around Sharm El-Sheikh area, in the northern Red Sea, female and male specimens of the poorly known calanoid copepod *Macandrewella cochinensis* Gopalakrishnan, 1973 were collected. This is the first record of species occurrence in the Red Sea. *Macandrewella cochinensis* was previously known only from the offshore water of Cochin, south west of India. The Red Sea specimens are described in details herein to allow their comparison with the specimens from the type locality, because original description of *M. cochinensis* is incomplete and causes some taxonomic confusion. The most important characters that may have been overlooked in the original description are: shape of projections of the female distolateral prosomal borders, details of morphology of the asymmetrical female genital double-somite and presence of leg 5 in female.

Keywords

Zooplankton, copepods, *Macandrewella cochinensis*, swarm, Red Sea

Introduction

Members of the family Scolecitrichidae are distributed from pelagic to benthopelagic waters of the world oceans. The boundaries of the family Scolecitrichidae are not well defined as reported by Vyshkvartzeva (2001), Ohtsuka et al. (2003) and Boxshall and Halsey (2004). Boxshall and Halsey (2004) have considered this family to contain about 23–26 genera, however, less number of genera have been included in the family by Markhaseva and Ferrari (2005).

The genus *Macandrewella* Scott, 1909 belongs to the family Scolecitrichidae and has so far accommodated 12 nominal species (Razouls et al. 2013). The genus has hitherto been recorded exclusively from tropical and subtropical waters between 30°N and 20°S in the Indo-Pacific waters (Ohtsuka et al. 2002). Most members of the genus are hyperbenthic and have been collected from the near bottom samples on the continental shelves and slopes. Ohtsuka Nishida and Nakaguchi described in 2002 *M. stygiana* and *M. omorii* from the southern Japan from the near bottom at depth of 95–467 m. Farran (1936) collected three species (*M. asymmetrica*, *M. mera* and *M. sewelli*) from the Great Barrier Reef when a plankton net accidentally touched the bottom at a depth of 200 m. *Macandrewella cochinensis* described by Gopalakrishnan (1973) was found from 200 m to the surface, *M. joanae* was sampled by Scott (1909) from 1000 m to the surface. Other species were collected in vertical or surface plankton hauls where no exact depths of collection were specified (Ohtsuka et al. 2002). Ohtsuka et al. (2002) gave an excellent review and a key for all *Macandrewella* species recorded worldwide on the basis of shape of female genital double-somite, presence or absence of a female leg 5, the structure of the second and third exopodal segments of the male right leg 5 and the shape of the right endopod segment of the male leg 5.

Only one species *M. chelipes* Giesbrecht, 1896 has been recorded from the Red Sea (Giesbrecht 1896, Campaner 1989, El-Sherbiny 1997). During our plankton sampling in the Red Sea, another species of *Macandrewella* was first time found in swarms at surface waters. It is identified as *M. cochinensis* which up to now has only been recorded from the type locality off Cochin, south coast of India (10°10'N, 75°46'E). This paper describes *Macandrewella cochinensis* collected near a reef in a semi-enclosed small shallow bay in the northern Red Sea. Its habit of swarming in surface waters is also discussed.

Materials and methods

The specimens were collected from the entrance of a semi-enclosed bay called Sharm El-Maya (6–9 m in depth), the northern Red Sea (27°51.234'N, 34°17.605'E, Fig. 1) at 4 PM local time on 5th of December 2011. The plankton samples were collected within 50 m of a fringing reef using a plankton net (diameter 1m, mesh size 0.5

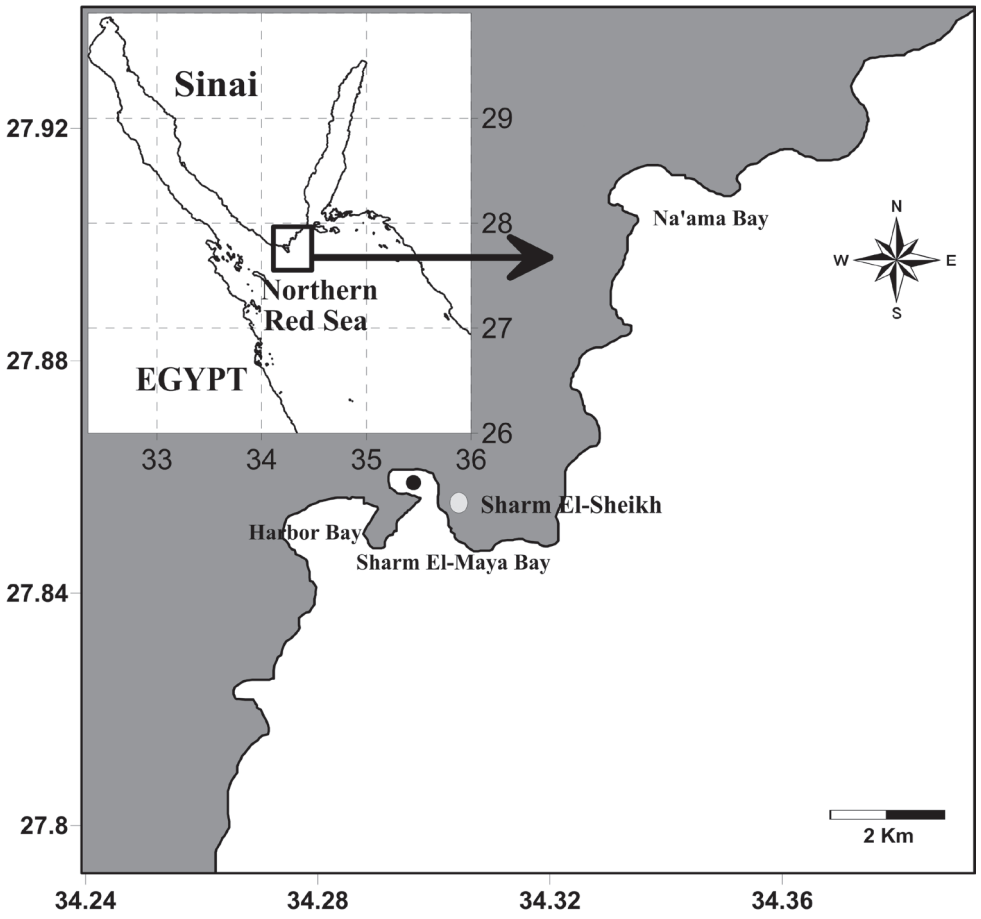

Figure 1. Location of the sampling site (Black circle).

mm). The net was towed for 10 minutes at a speed of about 2 knots. The collected specimens were concentrated and fixed in a 4% neutralized formalin-seawater solution immediately after collection and then transferred in 70% ethanol, sorted and examined using differential interference contrast microscope (Olympus BH-2 and CX41). Drawings were made with the aid of a camera lucida and all measurements were made using an ocular micrometer. The terminology in the description follows Huys and Boxshall (1991). For scanning electronic microscopy (SEM), whole copepods or dissected parts were mounted on stubs, dehydrated with liquid nitrogen, coated with white gold, and examined in a JEOL, JSM-5600LV scanning electron microscope. Specimens are deposited at the Zoological Institute, Russian Academy of Science, Saint Petersburg, Russian Federation (No. 91067) and in the Marine Science Department, Suez Canal University, Egypt. Stages and sexes of individuals comprising the swarm were identified.

Systematics

Order Calanoida Sars, 1903
Family Scolecitrichidae Giesbrecht, 1892
***Macandrewella* A. Scott, 1909**

***Macandrewella cochinensis* Gopalakrishnan, 1973**
http://species-id.net/wiki/Macandrewella_cochinensis
Figs 2–7

Material examined. Nine adult females and eight adult males collected from Sharm El-Maya Bay located in the entrance of Sharm El-Sheikh City, the northern Red Sea on 5 December 2011.

Body length. Female: 2.88–3.15 mm (mean±SD=2.99±0.09 mm, *n*=6). Male: 2.83–3.21 mm (2.98±0.13 mm, *n*=6).

Female. Body (Fig. 2A) robust; cephalosome completely fused to first pediger, protruding anteroventerally into bifurcated rostrum; rostrum (Figs 2B–C) with pair of slender filaments; single median cuticular lens present at base of rostrum (Figs 2B–C, 3A). Pedigers 4 and 5 partially fused, with incomplete suture visible dorsally and ventrolaterally; posterior margin asymmetrical, left one longer; each with 1 pairs of processes on each side, postero-dorsolateral projecting on each side lamellar with serrated margin, asymmetrical ventrolateral processes curved ventromedially at tip, slightly exceeding the posterior end of genital double somite on left side and slightly exceeding half length of genital double-somite on right (Figs 2D, 3B, D). Urosome (Figs 2E, D) short, approximately one-fifth as long as prosome; of 4 free somites. Genital double-somite asymmetrical with unequal anterodorsal protrusion on each side and posterodorsal swelling on left side (Figs 2F, G, 3C, D); genital area usually with sausage-like spermatophore (Fig. 2F); genital operculum wider than long, located distoventrally (Fig. 2E). Fourth urosomite (anal somite) very short, telescoped into proceeding somite. Caudal rami symmetrical with 5 caudal setae, left middle seta (V) 1.5 times as long as right one.

Antennules (Figs 2H, I) symmetrical, 23-segmented, extending nearly to posterior border of second somite. Segmentation pattern and setal armature elements as follows: I-3, II-IV, 6+ae (II-2, III-2+ae, IV-2), V-2+ae, VI-2, VII-1+ae, VIII-2, IX-2+ae, X-XII-4+ae, XIII-1, XIV--2+ae, XV-1, XVI-2+ae, XVII-1, XVIII-1, XIX-1, XX-2, XXI-1+ae, XXII-1, XXIII-1, XXIV-1+1, XXV-1+1, XXVI-1+1, XXVI-XXVIII-5+ae.

Antenna (Fig. 4A) coxa with 1 plumose seta medially and lateral array of curved setules; basis with 2 mediodistal setae of unequal length. Exopod 7-segmented with setal formula of 0, 0-0-1, 1, 1, 1, 1, 1+3 setae; endopod 2-segmented, first segment with 2 subterminal setae and patch of fine setules medially, distal segment bearing 8 setae on middle lobe, terminal lobe with 7 setae and patch of fine setules.

Mandible gnathobase (Fig. 4B) heavily sclerotized with cutting edge bearing 8 teeth (5 of them flattened with broad edge) and spinulose seta. Palp (Fig. 4C) basis

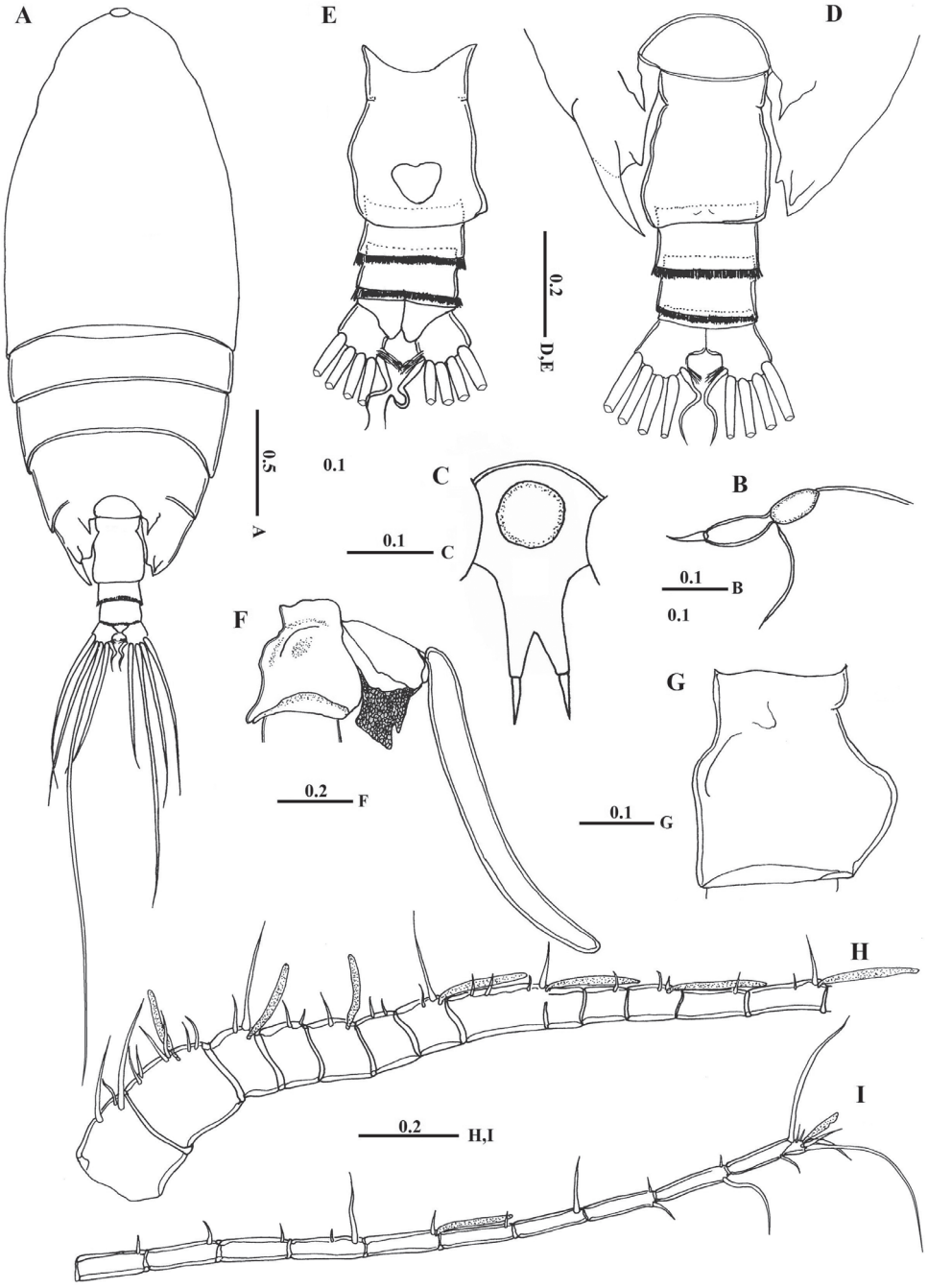

Figure 2. *Macandrewella cochinensis* female from the northern Red Sea. **A** habitus, dorsal view **B** rostrum, lateral view **C** rostrum, ventral view **D** posterior prosome and urosome, dorsal view **E** urosome, ventral view **F** genital double-somite with spermatophore, lateral view (right) **G** genital double-somite, lateral view (right) **H–I** antennules. All scale bars in mm.

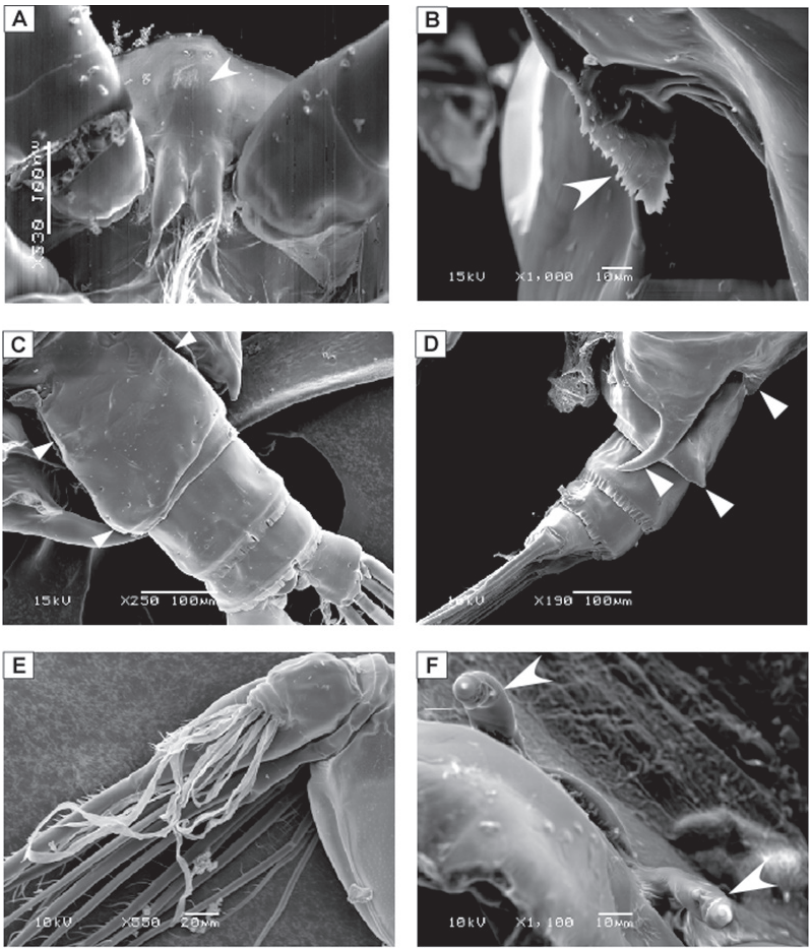

Figure 3. SEM micrographs of *Macandrewella cochinensis* female from the northern Red Sea. **A** rostrum and cuticular lens indicated by arrow, ventral view **B** serration of postero-dorsolateral process of prosomal end indicated by arrow, lateral view **C** urosome, anterodorsal protrusions and posterodorsal swelling on left side indicated by arrows, dorsal view **D** urosome, posterodorsal swelling on left side indicated by arrow, lateral view (left) **E** maxillary endopod **F** leg 5 indicated by arrow.

longer than wide, bearing 2 spinulose setae; exopod consisting of 5 segments with setal formula of 1, 1, 1, 1, 2; endopod 2-segmented, with 2 setae on first segment and 9 setae and row of fine spinules on second segment.

Maxillule (Fig. 4D) with praecoxal arthrite bearing 13 setae, 9 setae along terminal border, 4 setae on posterior surface and 1 seta on anterior surface (Fig. 4D). Coxal endite bearing 2 setae; coxal epipodite with 9 setae; basis completely fused with endopod; first and second basal endites with 3 and 5 setae respectively; baseoendopod with 7 setae terminally; exopod lobate, bearing 8 setae.

Maxilla (Figs 4E, F) praecoxal endite 1 with 4 setae, second praecoxal to second coxal endites each bearing 3 setae; basis with 2 setae and 2 worm-like sensory setae and

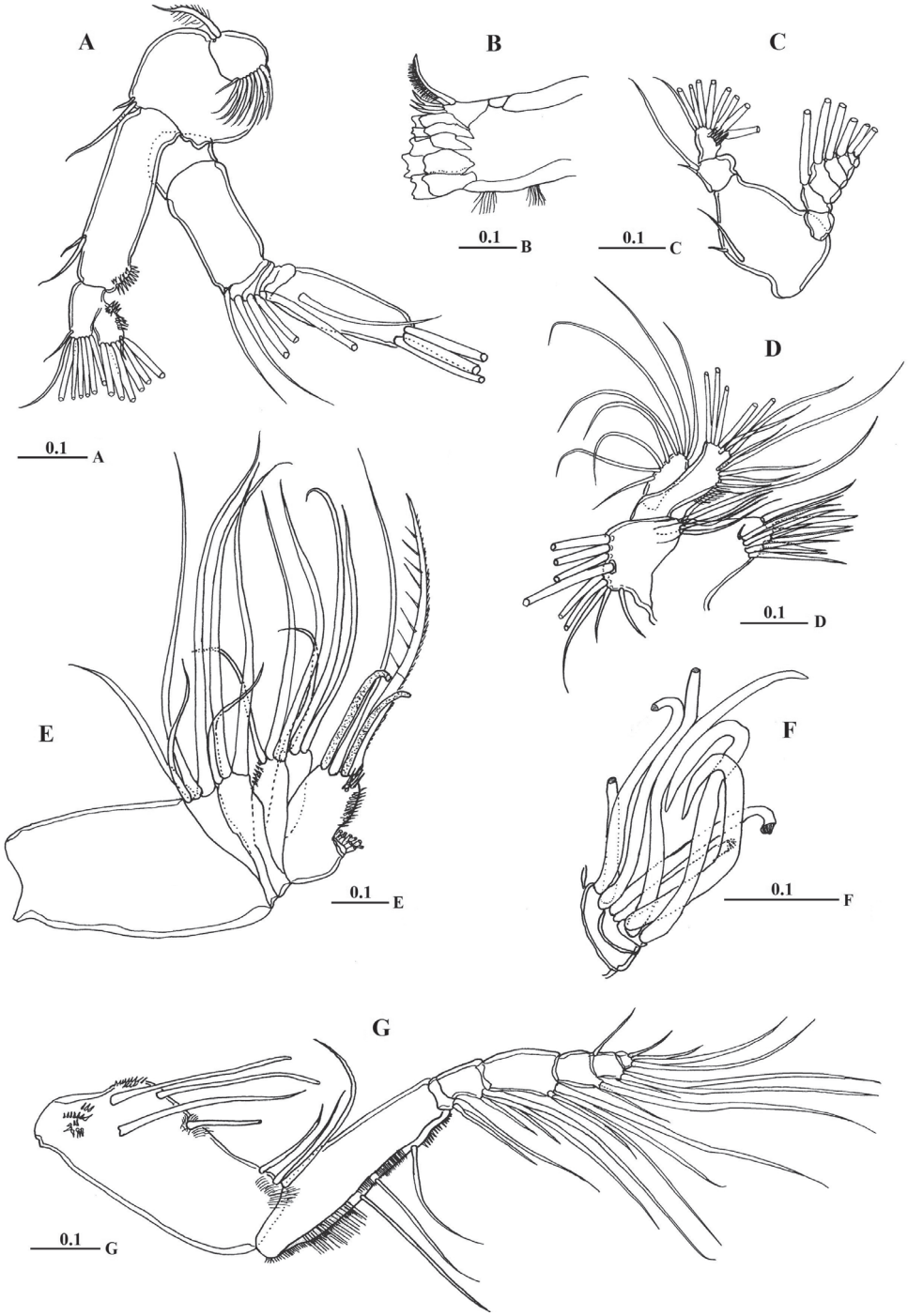

Figure 4. *Macandrewella cochinensis* female from the northern Red Sea. **A** antenna **B** mandibular gnathobase cutting edge **C** mandibular palp **D** maxillule **E** maxilla **F** maxilla endopod **G** maxilliped. All scale bars in mm.

Table 1. Spines and setae formula of leg 1–4 of *Macandrewella cochinensis* collected from the northern Red Sea.

			Exopod			Endopod		
	Coxa	Basis	1	2	3	1	2	3
Leg 1	0-0	0-1	I-0;	I-1;	I,1,3	0,2,3		
Leg 2	0-1	0-0	I-1;	I-1;	III,I,4	0-1;	1,2,2	
Leg 3	0-1	0-0	I-1;	I-1;	III,I,4	0-1;	0-1;	1,2,2
Leg 4	0-1	0-0	I-1;	I-1;	III,I,4	0-1;	0-1;	1,2,2

Note: Roman numeral: spines; Arabic numeral: setae.

patch of fine spinules. Endopod (Figs 3E, 4F) indistinctly three-segmented, bearing 3 brush-like, 2 brush-like and 3 worm-like sensory setae, respectively.

Maxilliped (Fig. 4G) praecoxal endites of syncoxa with 2 worm-like and 1 hirsute setae proximally, and 1 brush-like setae at nearly mid-length; coxal endite with 3 setae located at distal end. Basis nearly as long as syncoxa with submarginal row of minute spinules and 3 setae along medial margin. Endopod 6-segmented; first endopodal segment very short and almost incorporated into basis bearing 2 setae; second to sixth endopodal segment with setal formula of 4, 4, 3, 3+1, 4.

Legs 1 to 4 biramous, with 3-segmented exopods; endopod 1-segmented in leg 1, 2-segmented in leg 2, 3-segmented in legs 3 and 4. Spines and setal formula are shown in Table 1. Leg 1 (Figs 5A–C) smallest, first exopodal segment with expanded medial margin bordered by naked lateral spinules (Fig. 5B), middle segment bearing lateral spine and medial seta, distal exopod segment with serrate spine and spiniform terminal seta; endopod bearing middle lateral knob with patch of fine setules terminally (Fig. 5C). Leg 2 (Fig. 5D) coxa and basis with pointed prominence on lateral margin; second exopodal segment with crescent-like row of spinules on posterior surface; third segment with middle patch of spinules posteriorly; first endopodal segment without any spinules; second endopodal segment bearing 6 acute spinules . Leg 3 (Fig. 5E) coxa with pointed prominence on lamellar lateral margin; basis with pointed process on medial distal corner; second exopodal segment with crescent-like row of spinules along distal margin, third segment with minute spinules distributed in curved row; second and third endopodal segments bearing 4 and 6 spinules, respectively. Leg 4 (Fig. 5F): second and third exopodal segments each bearing longitudinal row of stout spinules distributed as shown in Fig. 5F. Shape, number and distribution of spinules along second and third exopodal segment varies among individuals (Figs 5G,H).

Leg 5 (Fig. 5I) rudimentary, 2-segmented separated at base; each terminal segment cylindrical with medial papilla-like protrusion and constriction at one-third distal part (see also Fig. 3 F).

Male. Body (Figs 6A, B) more slender than female; rostrum bifurcated with pair of filaments; cuticular median lens present at base of rostrum. Cephalosome completely fused with first pediger, fourth and fifth pedigers fused with suture visible laterally; border of fifth pediger symmetrical, ending with paired stout ventrally-curved process-

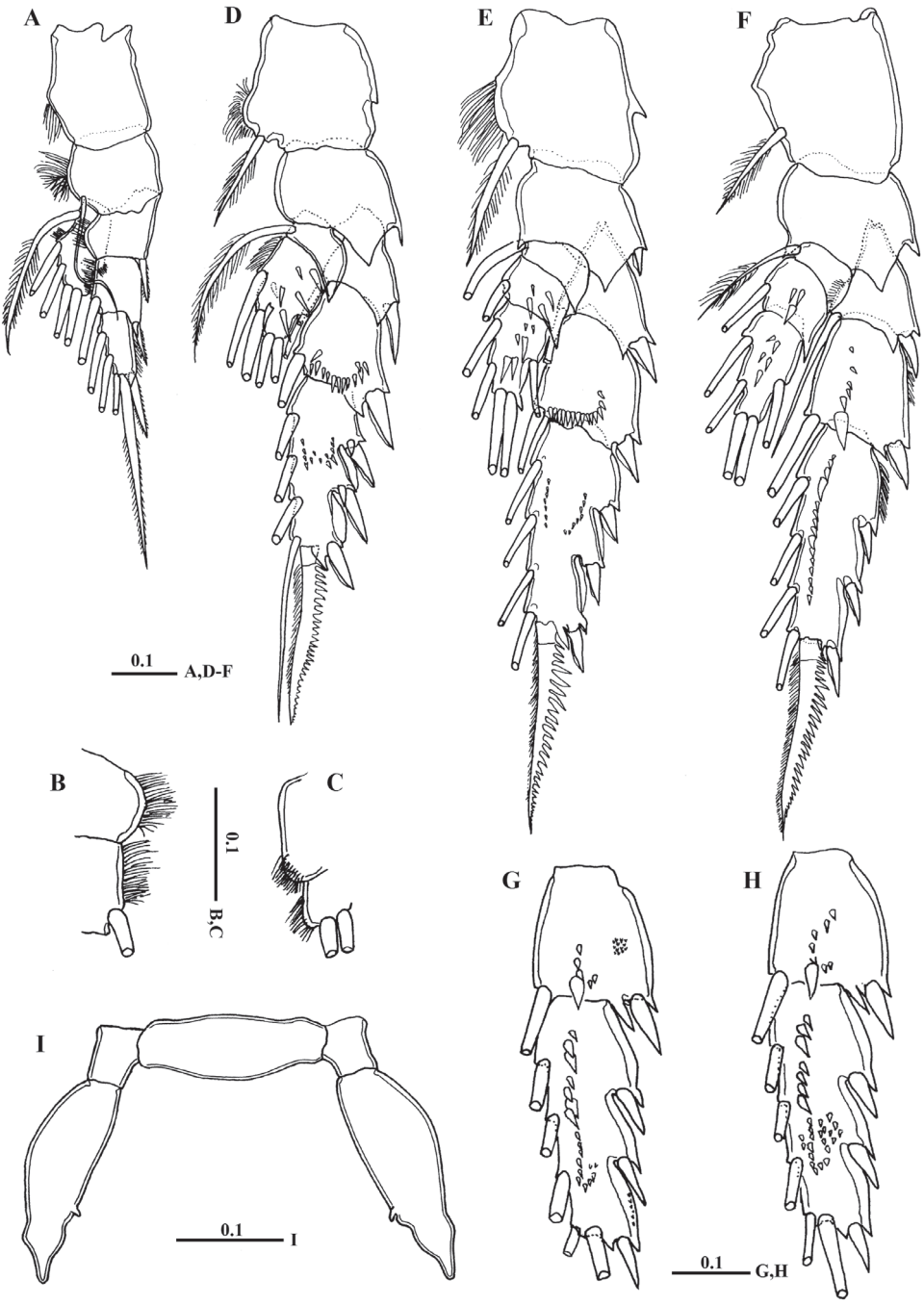

Figure 5. *Macandrewella cochinensis* female from the northern Red Sea. **A** Leg 1, anterior surface **B** medial margin of first and second exopodal segments of Leg 1 **C** lateral distal margin of leg 1 endopod **D** leg 2, posterior surface **E** Leg 3, posterior surface **F** leg 4, posterior surface **G–H** second and third exopodal segments of leg 4, anterior surface **I** leg 5, anterior surface. All scale bars in mm.

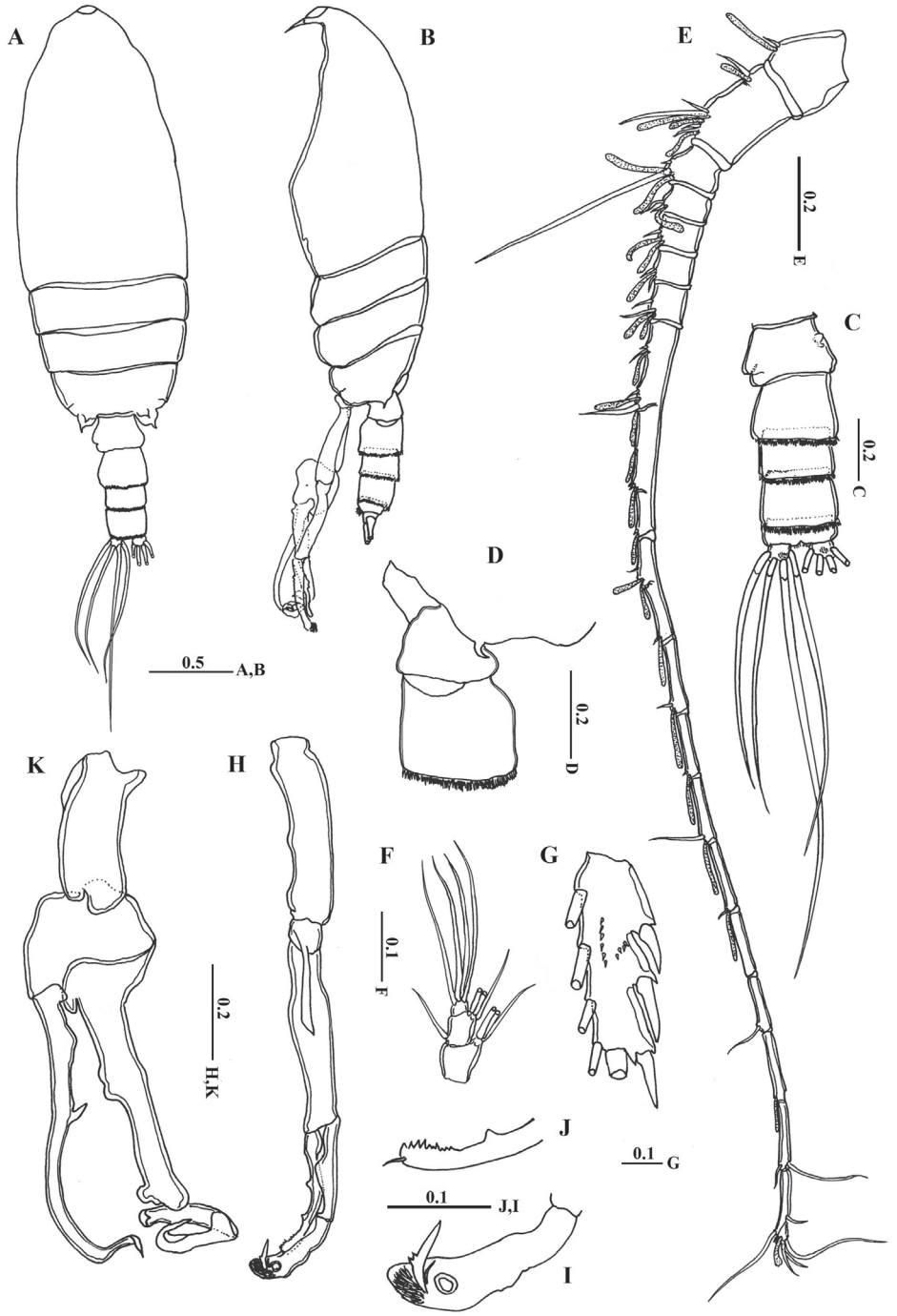

Figure 6. *Macandrewella cochinensis* male from the northern Red Sea. **A** habitus, dorsal view **B** habitus, lateral view **C** urosome, dorsal view **D** first and second urosomal segment, lateral view (right) **E** left antennule **F** maxilliped, terminal endopod segments **G** Exopod segment 3 of leg 2 **H** left leg 5 **I** terminal portion of left exopodal of leg 5 **J** terminal portion of left endopod of leg 5 **K** right leg 5. All scale bars in mm.

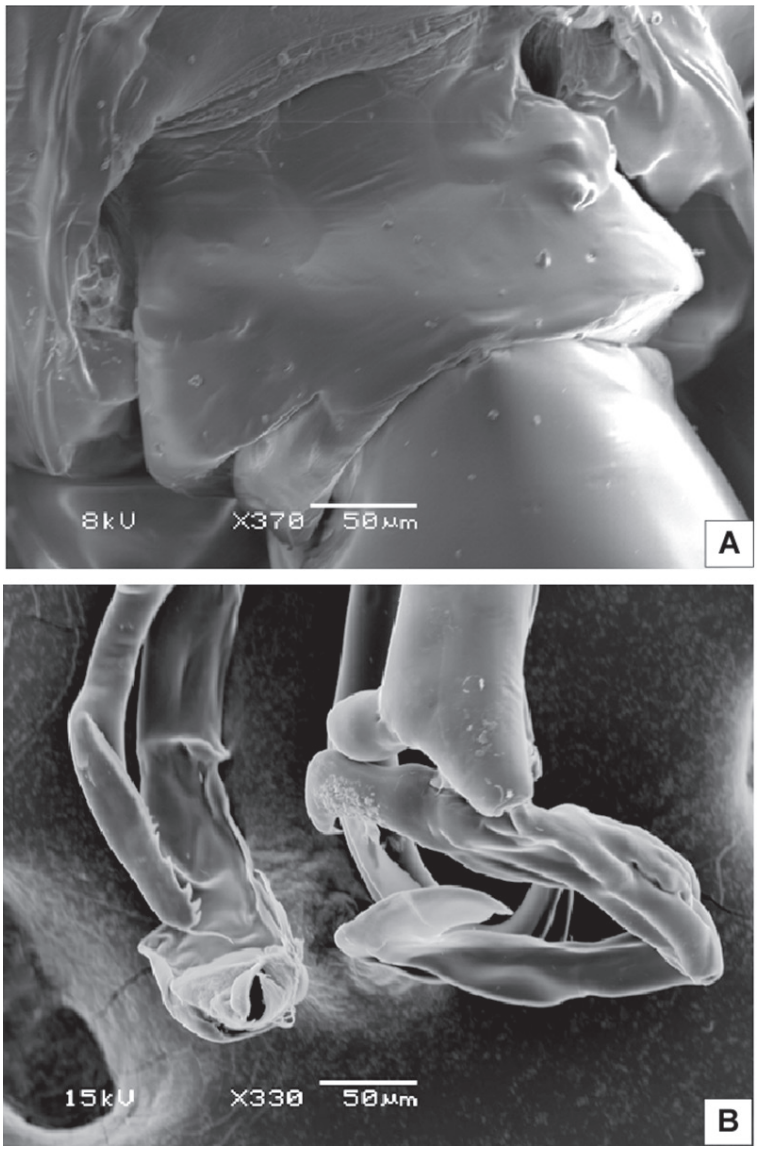

Figure 7. SEM micrographs of *Macandrewella cochinensis* male from the northern Red Sea. **A** genital somite, dorsal view **B** distal part of leg 5.

es. Urosome (Fig. 6C) 5-segmented; genital somite asymmetrical, with anterior dorsal knobs on right side (Figs 6C, D, 7A); second to fourth urosomites with thin spinules along posterior margin; second urosomite slightly asymmetrical in dorsal view, anal somite very small; caudal rami symmetrical, each ramus bearing 4 plumose setae.

Antennule (Fig. 5E) consisting of 18 and 19 articulated segments on right and left side, respectively. Setal formula of left antennule as follows: I-1+ae, II-IV-6+4ae (II-2+ae, III-2+2ae, IV-2+ae), V-2+2ae, VI-2+ae, VII-2 (1 missed)+2ae, VIII-2+ae,

IX-2+2ae, X-XV-7+6ae, XVI-XVII-2+3ae, XVIII-1+ae, XIX-1+ae, XX-1+ae, XXI-1+ae, XXII-unarmed, XXIII-1, XXIV-1(missed)+ae, XXV-1+1, XXVI-1+1, XXVII-XXVIII-5+ae. Right antennules of 18 free segments with fusion of segments XXII and XXIII; setal formula of I-1+ae, II-IV-6+4ae, V-2+2ae, VI-2+ae, VII-1+ae, VIII-2+ae, IX-2+2ae, X-XV-5+6ae, XVI-XVII-2+3ae, XVIII-1+ae, XIX-1+ae, XX-1+ae, XXI-1+ae, XXII-XXIII-1, XXIV-1+1+ae, XXV-1+1+ae, XXVI-1+1, XXVII-XXVIII-5+ae.

Mouth parts and legs 1-4 similar to those of female except fifth and sixth endopodal segment of maxilliped with longer setae (Fig. 5F) and third exopodal segment of leg 2 with different number and distribution of posterior surface setules (Fig. 5G).

Leg 5 (Figs 6H–K) elongated in general structure resembling that of the other species of the genus. Left leg (Fig. 6H) with coxa approximately as long as basis; basis with longitudinal keel–like structure along proximal half; exopod 2–segmented, second segment with lamellar plate covered with dense tuft of cilia and 2 elements terminally (Figs 6I, 7B); endopod one-segmented, shorter than exopod, bearing 2 medial triangular processes, one seta at tip and medially serrated margin (Fig. 6J). Right leg chelate (Fig. 6K); coxa with triangular expansion proximally; basis expanded laterally; first exopodal segment bearing 3 medial processes, one located proximally, middle irregular and distal somewhat triangular; second exopodal segment short, bearing internally directed process truncate curved at tip; third segment as long as previous segment, curved inward distally (Fig. 7B); endopod one-segmented, curved outward and recurved at tip, bearing round process distally and triangular process midway.

Density and abundance of swarm

The density of *M. cochinensis* (adult and copepodites) in the studied area was about 422 individuals m^{-3}. Adults constituted the major part of the swarm (72.5%), while copepodids consisted mainly of the fourth (CIV) and fifth (CV) stages, forming only 27.5%. Among adults, males show a slightly higher percentage in the population than females (38.1 and 34.4 % respectively). On the other hand, male copepodids (26.0%) outnumbered females (1.5%).

Discussion

Original description of *Macandrewella cochinensis* by Gopalakrishnan (1973) is not enough detailed and contain only brief data on *Macandrewella* key characters valuable in congeners identification (Ohtsuka et al. 2002), e.g. projections of the female posterior prosomal borders, type of genital double-somite asymmetry, and female leg 5 present, or absent. In general, morphological characters of *Macandrewella* specimens collected from the northern Red Sea correspond to *M. cochinensis* and they are currently attributed to this species. However, their taxonomic status is expected to be proved when additional specimens from the *M. cochinensis* type locality will be obtained.

The studied specimens from the Red Sea differ from *M. cochinensis* sensu Gopalakrishnan (1973) in the following characters of females (features of Gopalakrishnan specimens are given in brackets): 1) pedigers 4 and 5 fused (separate); 2) pediger 5 with 2 pairs of processes, both dorsolateral projecting lamellar with serrated margin (apparently overlooked); 3) genital double-somite with asymmetrical anterodorsal protrusion on each side and posterodorsal swelling on left side (not described, only mentioned it is asymmetrical); 4) antennary first endopodal segment with 2 setae subterminally (1 seta); 5) endopodal middle lobe of distal segment with 8 setae (7 setae); 6) endopodal terminal lobe of distal segment bearing 7 setae (6 setae); 7) antennary second exopodal segment with long setae (seta shorter); 8) mandibular palp with basis carrying 2 setae (1 seta); 9) endopod segment 2 with 9 setae (10 setae); 10) maxillule praecoxal artherite with 13 setae (9 setae); 11) maxillule coxal epipodite bearing 9 setae (8 setae); 12) maxillule second basal endite with 5 setae (4 setae); 13) maxillule baseoendopod with 7 terminal setae (6 setae); 14) maxilliped endopod with setal formula of 2, 4, 4, 3, 3+1, 4 (vs 2, 4, 4, 3, 2+1, 4); 15) leg 3 basis with lateral prominence (absent); 16) surface spinulation of swimming legs is more dense than in the original description; 17) leg 5 rudimentary, composed of 2 segments (apparently overlooked). Males from the Red Sea and described by Gopalakrishnan (1973): differ in second exopodal segment of left leg 5 with 1 seta and 1 element terminally (1 element).

Macandrewella cochinensis closely resembles *M. stygiana* Ohtsuka, Nishida & Nakaguchi 2002 in dorsolateral processes on the prosomal ends of the female serrated and in the left ventrolateral process of the prosomal border extending nearly posterior margin of the genital double-somite. However, *M. cochinensis* is readily distinguishable from *M. stygiana* in the following characteristics: 1) the second and third urosomites are nearly equal in length (second urosomite longer than third one in *M. stygiana*); 2) female caudal left seta V 1.5 times longer than right (more than 2 times longer in *M. stygiana*); 3) female leg 5 is cylindrical, composed of 2 segments with 1 medial process and a constriction on the distal third of the distal segment (more flattened in *M. stygiana*); 4) the lateral middle process of the right endopod of male leg 5 is larger (smaller); 5) the lack of a medial distal process of the second exopodal segment of male right leg 5 (present); 6) the distal exopodal segment of male right leg 5 is relatively narrower in *M. cochinensis* (broader in *M. stygiana*).

The female of *M. cochinensis* is also similar to that of *M. joanae* Scott 1909 collected from Halmahera Sea, Indonesian Archipelago, but can be distinguished by the presence of ventrolateral processes on the distal prosomal borders that reach nearly to the midlength of the genital double-somite; the genital operculum is wider than long; the left middle seta on the caudal ramus is nearly 1.5 times as long as the right one but shorter than in *M. joanae*; the terminal segment of the female leg 5 is more reduced than in *M. joanae* and has no terminal elements.

Swarm formation is known in coastal and deep-sea calanoid families such as Acartiidae, Calanidae, Centropagidae, Pontellidae, Pseudodiaptomidae, Ridgewayiidae, Spinocalanidae, Temoridae, and Tortanidae (e.g. Hamner and Carleton 1979, Fleminger 1983, Ueda et al. 1983, Mauchline 1998, Heidelberg et al. 2010). However these species

except for the Spinocalanidae form multispecies assemblages (Fleminger 1983, Mauchline 1998, Ivanenko et al. 2007). This is the first record of the family Scolecitrichidae to form a monospecific aggregation. The adaptive meaning of copepods' swarming is interpreted as being possibly related to: (1) antipredation against visual predators; (2) reduction of dispersion by currents; (3) facilitating and enhancing mating opportunity; (4) keeping position to feed on coral mucus (Mauchline 1998); (5) positioning in the volcanic gases (Fleminger 1983, Ivanenko et al. 2007). In case of *Macandrewella cochinensis*, the dominance of adult and swarming position near the surface are peculiar, suggesting the likelihood of the above-mentioned first and third possibilities. Many studies showed that most members of the family Scolectrichidae are detritivores (e.g. Nishida et al. 1991, Nishida and Ohtsuka 1997). Regarding *Macandrewella*, Ohtsuka et al. (2002) in their study concluded that this genus is omnivorous voraciously feeding mostly on small crustacean carcasses and/or sloughs as well as radiolarians and diatoms.

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A review of the Nearctic genus *Zealeuctra* Ricker (Plecoptera, Leuctridae), with the description of a new species from the Cumberland Plateau region of eastern North America

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Abstract

The stonefly genus *Zealeuctra* (Plecoptera: Leuctridae) is endemic to the central and eastern Nearctic regions and is presently comprised of 10 species. Scanning electron microscopy (SEM) was used to examine and redescribe two important diagnostic features typically used to identify and define the adult male stage: the large, anteriorly-recurved epiproct and the medial cleft of the ninth abdominal tergite. SEM was also employed to depict the posteromedial portion of female 7th sternum. A new species, *Z. ukayodi* **sp. n.**, is described from the Cumberland Plateau region of northeastern Alabama and Tennessee. The new species appears superficially similar to *Z. talladega* Grubbs, but is easily differentiated by characteristics of the male medial cleft. An updated taxonomic key to the males of *Zealeuctra* is provided.

Keywords
Plecoptera, Leuctridae, *Zealeuctra*, new species, North America

Introduction

The subgenus *Zealeuctra* Ricker, 1952 was erected to include *Leuctra claasseni* Frison (Ricker 1952). Illies (1966) later elevated *Zealeuctra* to full generic rank. *Zealeuctra* remained monotypic until the comprehensive study of Ricker & Ross (1969). Six new species were described: *Z. arnoldi* Ricker & Ross, 1969, *Z. fraxina* Ricker & Ross, 1969, *Z. hitei* Ricker & Ross, 1969, *Z. narfi* Ricker & Ross, 1969, *Z. wachita* Ricker & Ross, 1969, and *Z. warreni* Ricker & Ross, 1969. Poulton and Stewart (1991) subsequently described the male of *Z. wachita* since the original description of this species was based only on the female. Three additional species have since been described: *Z. cherokee* Stark & Stewart, 1973, *Z. stewarti* Kondratieff & Zuellig, 2004, and *Z. talladega* Grubbs, 2005 (Stark and Stewart 1973; Kondratieff and Zuellig 2004; Grubbs 2005).

Zealeuctra is endemic to the central and eastern Nearctic regions, and is typically associated with intermittent or temporary upland streams (Snellen and Stewart 1979; Stewart and Stark 2002). *Zealeuctra claasseni* and *Z. fraxina* are the only species distributed broadly. In contrast, three species are found mainly in the Texas Hill Country region (*Z. arnoldi*, *Z. hitei*, and *Z. stewarti*), three species are regional endemics within the Interior Plateau region (*Z. cherokee*, *Z. wachita*, and *Z. warreni*), *Z. narfi* is distributed from Arkansas and Missouri north to Wisconsin, and *Z. talladega* is known only from the Talladega Mountains region in eastern Alabama.

Zealeuctra exhibits several unique characteristics in the adult stage, namely the swollen male cerci with accessory humps and/or spines, the male ninth tergite bearing a conspicuous medial depression (i.e. "cleft"), and the female seventh sternite having a posteromedial lobe (although secondarily lost in two species; Ricker and Ross 1969). The two diagnostic features typically used to identify and distinguish between males are the (1) large, anteriorly-recurved epiproct and the (2) shape and sclerotization patterns of the cleft. The shape and arrangement of cercal lobes/spines can also aid with identifications (e.g. Poulton and Stewart 1991). In addition, the fused subanal plates-anal probe structure appears to offer diagnostic information yet this has not been fully studied. Identifying females to species is markedly easier if associated males are present. Females are identified by the hind margin of the seventh abdominal sternite, notably the (a) presence or absence of a central notch and lobe and (b) shape of the "shoulders" if a notch is present. *Zealeuctra* nymphs are uncommon in collections and only one species has been described in detail (*Z. claasseni*; Stewart and Stark 2002).

In this study scanning electron microscopy (SEM) was employed to examine two diagnostic features of *Zealeuctra* males, focusing on the epiproct and the abdominal cleft. The posteromedial portion of the female seventh abdominal segment is also depicted with SEM micrographs. A new species is described herein and an updated taxonomic key to the males of *Zealeuctra* is provided.

Materials and methods

Most of the *Zealeuctra* specimens examined in this study were obtained from the Monte L. Bean Museum, Brigham Young University, Provo, Utah, USA (BYUC), C.P. Gillette Museum, Colorado State University, Fort Collins, Colorado, USA (CSUC), S.A. Grubbs collection, Western Kentucky University, Bowling Green, Kentucky, USA (WKUC), B.P. Stark Collection, Mississippi College, Clinton, Mississippi, USA (BPSC), and the Illinois Natural History Survey, Champaign-Urbana, Illinois, USA (INHS). Other codens used were TAMU (Texas A&M University Insect Collection, College Station, Texas, USA), and USNM (National Museum of Natural History, Smithsonian Institute, Washington D.C., USA). Location data (in decimal degrees) for each specimen record were recorded either directly with portable GPS units or georeferenced from vial label data (if possible).

Specimens for SEM analyses were dehydrated through a series of 75%, 90%, 95%, and 100% ethanol for 10 minutes each, and placed in Hexamethyldisilizane for 30 minutes. Dehydrated specimens were attached to aluminum stubs with double-stick tape and coated with gold-palladium using an Emscope SC500. Coated specimens were examined using a Jeol JSM-5400LV scanning electron microscope and digital images were captured with an IXRF system.

Results and discussion

Ricker and Ross (1969, their figure 29) placed *Zealeuctra* in a polytomy with *Paraleuctra* Hanson, 1941, *Rhopalopsole* Klapálek, 1912, and *Leuctra divisa* Hitchcock, 1958 (the latter is now included in *Paraleuctra* (Stark & Kyzar, 2001)). They postulated that these taxa were grouped by two synapomorphies: females with an incomplete 10th abdominal sternite and the presence of membranous pleural folds on larval abdominal segments 1–6 (shared also by *Moselia* Ricker, 1943, (Stewart and Stark 2002)). Ricker and Ross (1969, their figure 28) proposed that the seven species of *Zealeuctra* recognized at that time were derived from a series of three basal ancestors, and that *Z. narfi* was the most ancestral species.

Testing Ricker and Ross's (1969) hypotheses, however, and assessing how those species described since 1970 fit within an evolutionary framework is mostly beyond the scope of this paper. This would require a comparative morphological assessment of the fused subanal plates-anal probe structure, and arguably more importantly, a modern and robust phylogenetic analysis using molecular techniques (e.g. mitochondrial cytochrome *c* oxidase I gene sequencing).

An updated taxonomic key to the males of *Zealeuctra* is provided, and a new *Zealeuctra* species is described herein from the Cumberland Plateau region of southern Tennessee and northeastern Alabama.

Key to *Zealeuctra* males, modified in part from Ricker and Ross (1969) and Poulton and Stewart (1991)

1 Cleft (=medial depression) tapering and V-shaped, especially in anterior half (Figs 3A–D, 5A) **2**

– Cleft distinctly U-shaped in anterior half (Figs 1A, 4A, 9A)..... **3**

2 Epiproct with a broad triangular base (Figs 3E–H); inner margins of cleft bearing several medial crenulations (Figs 3A–D); widespread distribution across the eastern and central USA (Fig. 12) ..... ***Z. claasseni*** **(Frison)**

– Epiproct base narrowly triangular and with a minor shelf-like anterior projection (Figure 5B); inner margins of cleft lacking crenulations and with only a single tooth-like medial projection in posterior half (Fig. 5A); known mainly from central Texas (Fig. 11)..... ***Z. hitei*** **Ricker & Ross**

3 Distal portion of epiproct with only one spine (Figs 2B, 8D, 9C) **4**

– Distal portion of epiproct comprised of two distinct spines (Fig. 4B) or one prominent spine plus a prominent, accessory posterior cusp (Figs 1C, 10B).... **9**

4 Epiproct spine very long and slender (Kondratieff and Zuellig 2004, their fig. 2); endemic to south-central Texas (Fig. 13)..... ..... ***Z. stewarti*** **Kondratieff & Zuellig**

– Epiproct spine markedly shorter, either lacking (Figs 2B, 6C, 9C) or bearing a prominent anterior shelf-like projection at base (Fig. 7E–F, 8C–E)..... **5**

5 Epiproct bearing a prominent shelf-like projection at base, either rounded and subquadrate (Figs 6F, 8C–8D) or angular and squarish (Figs 7D–D, 8E)..... **6**

– Epiproct base not as above (Figs 2B, 6C, 9C) **7**

6 Inner margins of cleft sinuous, without crenulations along inner margins (Figs 7A–7C); anterior, recurved portion of epiproct possessing a minute, medially-positioned hump (Figs 7D–F); known only from the southern Talladega Mountains region of eastern Alabama (Fig. 13)..... ***Z. talladega*** **Grubbs**

– Inner margins of cleft V-shaped to almost sinuous, bearing several large crenulations along inner margins on posterior half (Figs 8A–B); anterior, recurved portion of epiproct possessing a medial hump (Figs 8C–E); distributed across the southern Cumberland Plateau region from central Tennessee south to northeastern Alabama (Fig. 13)..... ***Z. ukayodi*** **Grubbs, sp. n.**

7 Anterior portion of cleft with a secondary U-shaped extension, with inner margins set apart from remainder of cleft, medial subtruncate thumb-like projections present at terminus of cleft (Fig. 9A); epiproct anteriorly recurved gradually from base to tip (Fig. 9C) ..... ***Z. wachita*** **Ricker & Ross**

– Cleft U-shaped, with margins concave and contiguous throughout entire length, two medially-projected terminal processes present at terminus of cleft (Figs 2A, 6A); epiproct recurved abruptly, ca. 90° degree angle anteriorly (Figs 2B, 6C)... **8**

8 Epiproct with a small, thickened, shelf-like structure posteriorly (Fig. 2B).... ..... ***Z. cherokee*** **Stark & Stewart**

– Epiproct lacking a posterior thickening (Fig. 6C)..... ***Z. narfi* Ricker & Ross**
9 Epiproct comprised of two prominent spines, a large posterior spine plus an accessory anterior spine (Fig. 10B) ..... ***Z. warreni* Ricker & Ross**
– Epiproct bearing only a small, subterminal cusp posterior to the main spine (Figs 1B, 4C) **10**
10 Epiproct base bearing a conspicuous, slightly concave cusp anteriorly (Figs 1B–C); known only from Texas (Fig. 12) ..... ***Z. arnoldi* Ricker & Ross**
– Epiproct base simple and lacking a prominent cusp, at most, only a very small rounded projection anteriorly (Fig. 4C); sporadically distributed across the central and eastern USA (Fig. 11) ..... ***Z. fraxina* Ricker & Ross**

***Zealeuctra arnoldi* Ricker & Ross**
http://species-id.net/wiki/Zealeuctra_arnoldi
Figs 1, 12

Zealeuctra arnoldi Ricker & Ross, 1969: 1114. Holotype ♂ (INHS), Sorrell Creek, 1 mi S of Hancock, Comal Co., Texas

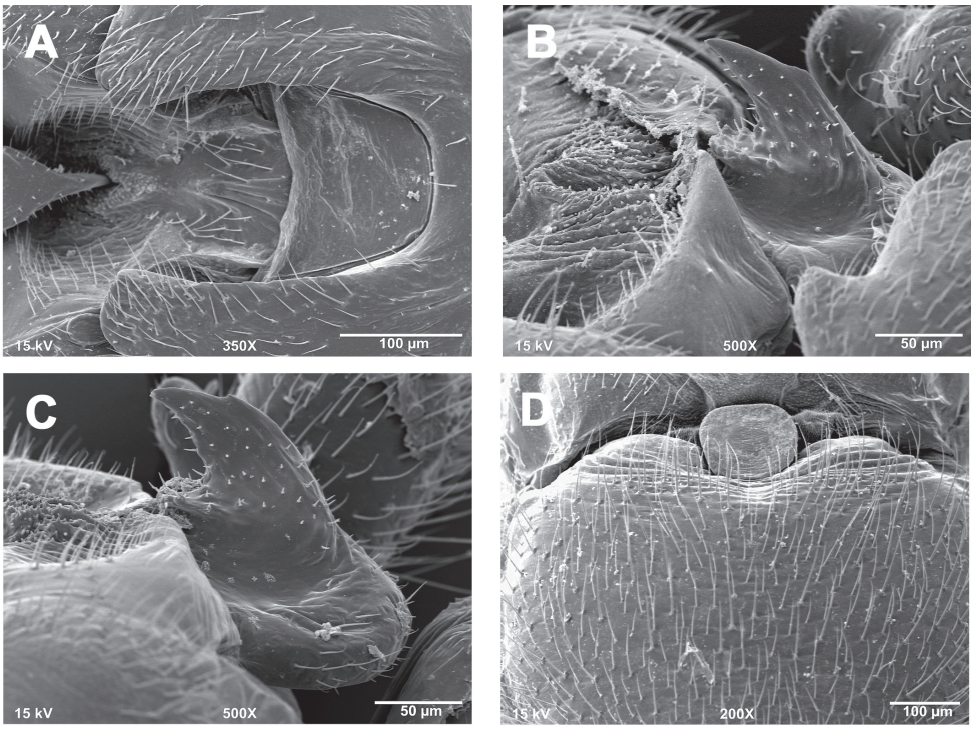
Description. Male - abdominal tergal cleft. Simple in outline. Anterior portion wide and broadly U-shaped, with a nearly straight terminal margin (Fig. 1A). Posterior portion narrowing slightly with no medial projections and only scarcely visible crenulations along inner margins.

Male - epiproct. Base short and robust, narrowing slightly to a short, recurved, subtriangular spine (Figs 1B–C). A short, slightly concave projection extends anteriorly from the base to approximately the same plane as the spine. Base with bulbous posterior swelling, spine with small accessory posterior cusp that is low and nub-like.

Female - 7th sternum. Seventh sternum with a large, subquadrate lobe nested in a distinct, central notch. The notch is bordered laterally by large, convex "shoulders" (Fig. 1D).

Material examined. USA, **Texas**: Bandera Co., Myrtle Creek, FR 2828 S of Camp Verde, 29.8242, -99.1347, 3.IV.2004, B.C. Kondratieff and R.E. Zuellig, 4♂, 13♀ (CSUC); Little Creek, Farm Rd. 470 E of Utopia, 29.6514, -99.4767, 3.IV.2004, B.C. Kondratieff and R.E. Zuellig, ♂ (CSUC); Hays Co., Barton Creek, Hwy 12, N of Dripping Springs, 30.2380, -98.0665, 14.III.1993, B.C. Kondratieff and R.W. Baumann, 5♂, 21♀(BYUC, CSUC); Paradise Hills, 25 January 1988, B.P. Stark, 2♂, 2♀ (BPSC); Travis Co., tributary of Barton Creek, near bowery of Hill Country Preserve in Bee Caves, downstream of Hwy 71, 20.III.1997, C.R. Nelson, 18♂, 13♀ (BYUC); Uvalde Co., Cherry Creek, Farm Rd. 1050 W of Utopia, 29.6061, -99.6925, 3.IV.2004, B.C. Kondratieff and R.E. Zuellig, 54♂, 38♀(CSUC); Bear Creek, Farm Rd, 1050 W of Utopia, 29.5989, -99.5664, 3.IV.2004, B.C. Kondratieff and R.E. Zuellig, 72♂, 68♀ (CSUC).

Distribution. USA: TX (DeWalt et al. 2012)



Figures 1. *Zealeuctra arnoldi*, scanning electron micrographs, USA, Texas, Uvalde Co., Cherry Creek, 3 April 2004. **A** male, cleft, dorsal view, 350× **B** male, epiproct, lateral view, 500× **C** male, epiproct, lateral view, 500× **D** female, posteromedial portion of seventh abdominal sternite, 200×.

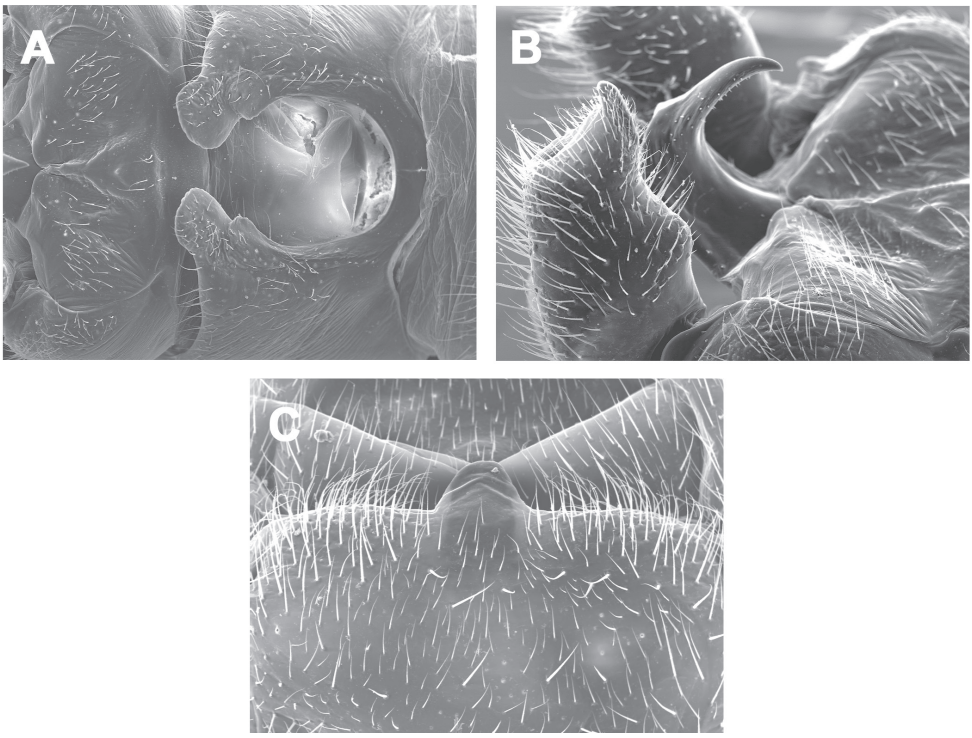
Remarks. This species is somewhat superficially similar to *Z. fraxina*. Males are easily identified by the combination of the simple, U-shaped cleft and the presence of the anterior, concave cusp present at the base of the short, compact epiproct spine. The depiction of the posterior cusp as pointed and acute in Ricker and Ross (1969, their Fig. 2) is not accurate and typically not visible. The cusp tends to be low and nub-like. This species is known mainly from the Edwards Plateau of west-central Texas (Fig. 12).

Zealeuctra cherokee Stark & Stewart

http://species-id.net/wiki/Zealeuctra_cherokee
Figs 2, 14

Zealeuctra cherokee Stark & Stewart, 1973: 192. Holotype ♂ (USNM), 2 mi W Vian, Sequoyah Co., Oklahoma

Description. Male - abdominal tergal cleft. Anterior portion U-shaped and very broadly rounded, posterior portion narrowing distally to a pair of medial projections,



Figures 2. *Zealeuctra cherokee*, scanning election micrographs, USA, Oklahoma, Adair Co., 9 mi S Stillwell, Hwy 59, 20 February 1972. **A** male, cleft, dorsal view, 200× **B** male, abdominal terminalia, lateral view, 350× **C** female, posteromedial portion of seventh abdominal sternite, 350×.

the terminal projection larger, subtruncate, and thumb-like, the subterminal projection smaller and subtriangular (Fig. 2A). Crenulations absent from inner margins of cleft.

Male - epiproct. Broad at base, extending posteriorly along one plane then extended abruptly and dorsally at a ca. 90 degree angle (Fig. 2B), spine tip slightly recurved anteriorly. No accessory spine or cusp present.

Female - 7th sternum. Seventh sternum with a small, subtriangular lobe nested in a distinct central notch (Fig. 2C).

Material examined. USA, **Arkansas:** Perry Co., Greathouse Creek, Hwy 216, 3 mi NE Thornburg, 34.9574, -92.7545, 7.IV.1984, B.C. Poulton, ♂ (CSUC); Sebastian Co., tributary to Sugar Creek, 5 mi SW Hartford, 17.II.1985, B.C. Poulton, ♂, ♀ (BYUC). **Oklahoma**: Adair Co., 9 mi S Stillwell, Hwy 59, 35.6917, -94.6691, 20.II.1972, B.P. Stark, 4♂, 5♀ (Paratypes, BPSC).

Distribution. USA: AR, OK (DeWalt et al. 2012)

Remarks. The cleft and epiproct spine of the male of this species are very similar to that of *Z. narfi*. The major difference for *Z. cherokee* is the presence of the posterior thickening along the recurved portion of the epiproct spine, and additionally, the subtruncate terminal medial processes at the posterior end of the cleft. The ranges of these two species broadly overlap in Arkansas and eastern Oklahoma (Fig. 14; Poulton and Stewart 1991).

***Zealeuctra claasseni* (Frison)**
http://species-id.net/wiki/Zealeuctra_claasseni
Figs 3, 12

Leuctra claasseni Frison, 1929 (in part): 404. Holotype ♂ (INHS), Bushy Fork, Herod, Illinois.
Leuctra claasseni Frison, 1935 (in part): 354.
Leuctra claasseni Frison, 1942 (in part): 256.
Leuctra (*Zealeuctra*) *claasseni* Ricker, 1952: 173.
Zealeuctra claasseni Illies, 1966: 120.
Zealeuctra claasseni Ricker & Ross, 1969: 1115.

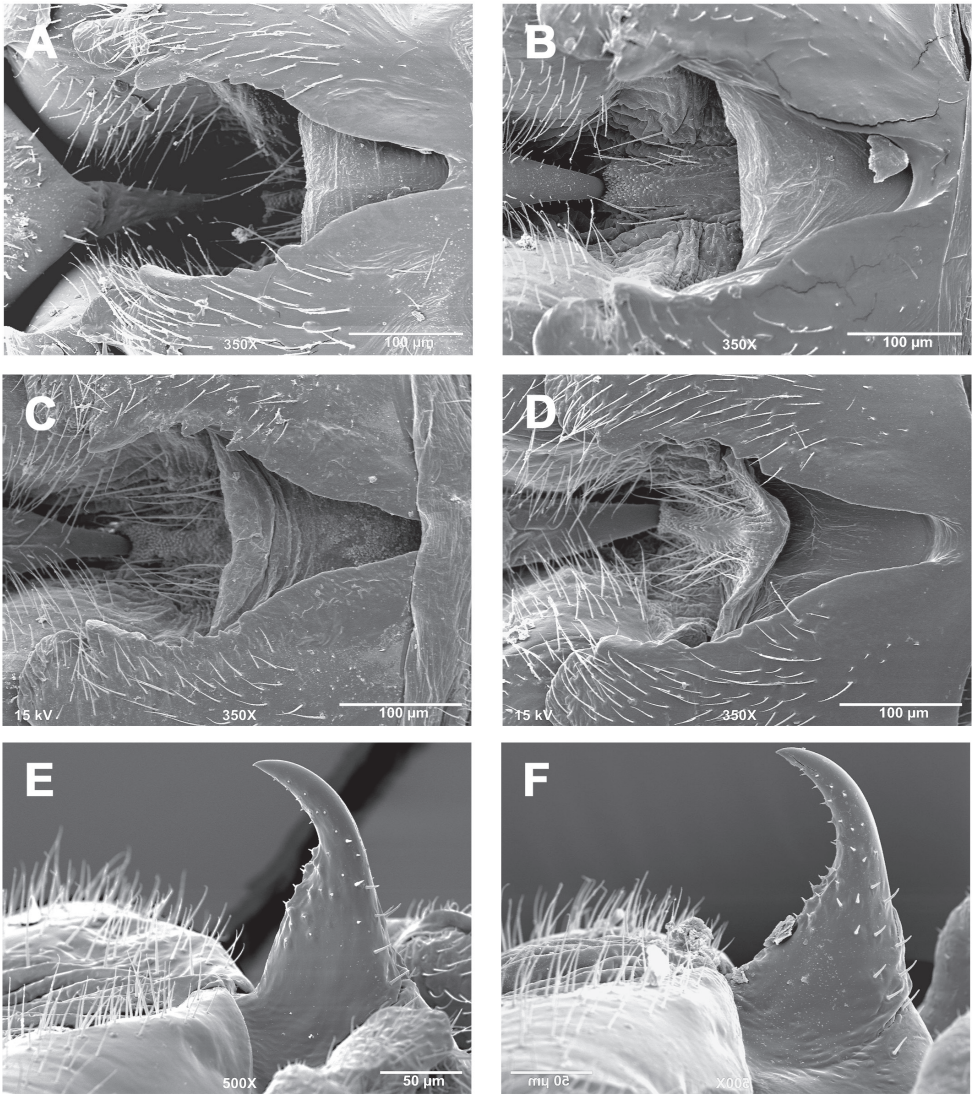
Description. Male - abdominal tergal cleft. Anterior portion V-shaped with slight inward medial swelling but lacking crenulations along inner margins, anterior terminus very narrowly rounded (Figs 3A–D). Posterior portion slightly more U-shaped with several irregularly-sized and rounded teeth projecting medially.

Male - epiproct. Triangular base narrowing to anteriorly-recurved and tapering terminal spine, no accessory spine or swelling present (Figs 3E–H). Conspicuous tubercles located on the anterior margins of the triangular base. No accessory spine or cusp present.

Female - 7th sternum. Seventh sternum with a small, variably-shaped lobe nested in a small central notch (Figs 3I–3L). The lobe ranges in shape from somewhat quadrate to broadly convex. The notch is likewise variably shaped, from essentially straight and scarcely perceptible (Figs 3I, 3K) to slightly concave (Figs 3J, 3L). Posterior margin essentially straight.

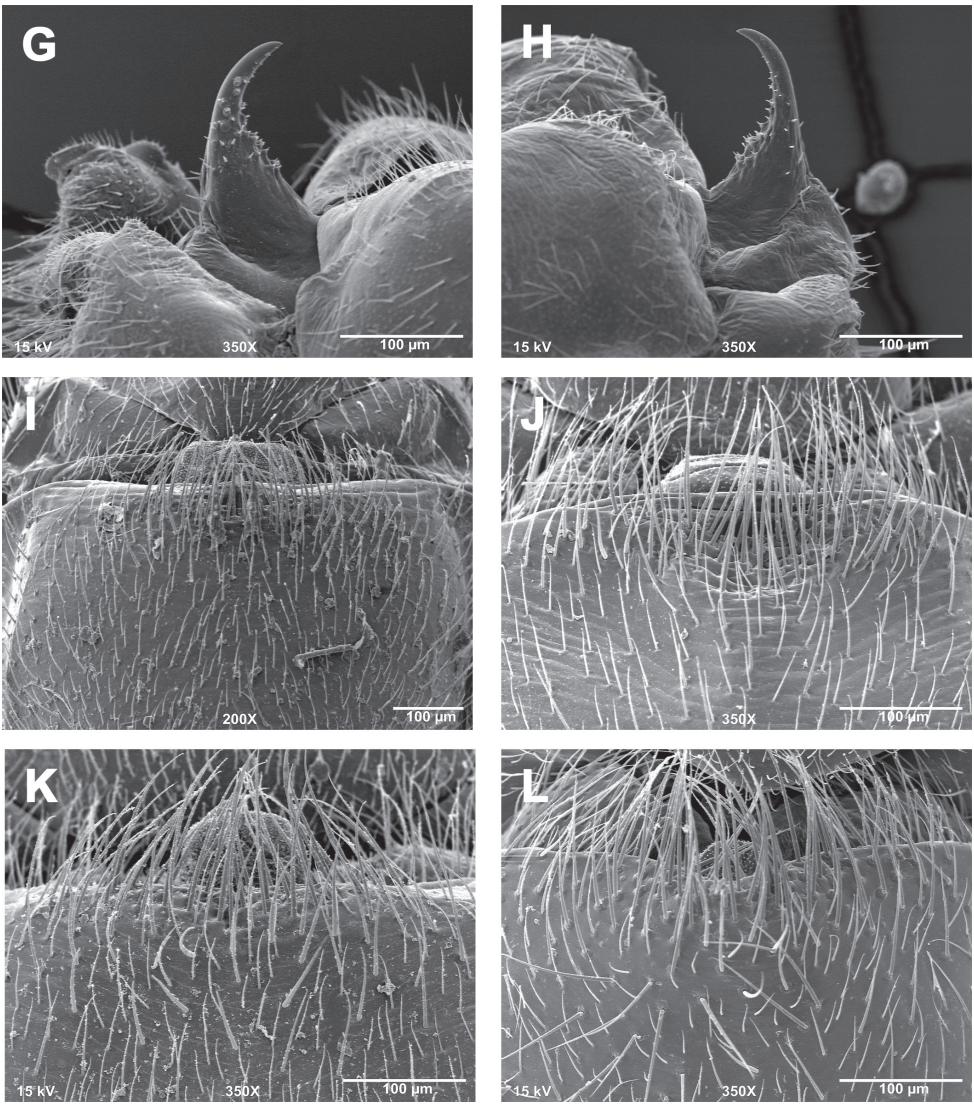
Material examined. USA, **Arkansas:** Baxter Co., High Tower Creek, Hwy 126 S of Monkey Run, 36.3369, -92.4743, 16.III.2002, B.C. Kondratieff and R.E. Zuellig, 31♂, 24♀ (CSUC); Logan Co., West Fork Hegwood Creek, Hwy 22, 3 mi E Paris, 35.2950,-93.6782, 21.III.1984, B.C. Poulton, 2♂, 3♀ (BYUC); Newton Co., Buffalo River, Hwy 21 bridge S of Boxley, 35.9610, -93.4042, 10.III.2002, B.C. Kondratieff and R.E. Zuellig, 8♂, 3♀ (CSUC). **Illinois:** Alexander Co., tributary to Sandy Creek, 4.8 km WNW Tamms, 37.2450, -89.3210, 25.IV.2001, D.W. Webb, ♂, ♀ (INHS); Hardin Co., Threemile Creek, 6.5 km WNW Elizabethtown, 5.IV.2000, R. E. DeWalt, ♂, ♀ (INHS); Jackson Co., tributary to Big Muddy River, Clear Springs Picnic Area, 3.5 km ESE Howardton, 37.6234, -89.4255, 7.IV.1992, M.A. Harris and M.J. Wetzel, ♂, ♀ (INHS); Pope Co., Burden Branch, Burden Falls, Shawnee National Forest, 37.5633, -88.6424, 20.IV.1992, D.W. Webb and M.A. Harris, ♂, 3♀ (INHS); Dog Creek, 9 km NW Hamletsburg at CR 1, Shawnee National Forest, 37.2041, -88.4914, 10.III.2011, R.E. DeWalt and M.R. Jeffords, 17♂, 9♀ (INHS); Gibbons Creek, 0.8 km N Herod, 37.5842, -88.4422, 5.IV.2000, R.E. DeWalt, ♂ (INHS); tributary to Lusk Creek, 0.8 km N Rising Sun, 37.4156, -88.5797, 28.III.2006, R.E. DeWalt, 3♂, 6♀ (INHS); Lusk Creek, SE of Eddyville, 37.4729, -88.5472, 28. III.2006, R.E. DeWalt, ♂, 3♀ (INHS). **Indiana:** Brown Co., Jackson Creek, 8 km W

Nashville, Yellowwood State Forest, 39.2075, -86.3461, 7.IV.2001, S.A. Grubbs, ♂, ♀ (WKUC); Spanker Branch, 14 km S Nashville, 39.0700, -86.2623, 7.IV.2001, S.A. Grubbs, ♂, 2♀ (WKUC); Skinner Creek, 8 km SSE Nashville, Brown County State Park, 39.1395, -86.2066, 7.IV.2001, S.A. Grubbs, 7♂, 6♀ (WKUC); Clark Co., Nine Penny Branch, 4 km NE Charleston, Nine Penny Branch Nature Preserve, 38.4772, -85.6318, 13.III.2000, S.A. Grubbs and J.M. Ferguson, 4♂ (WKUC); Crawford Co., small spring-fed stream, Rich Cave Hollow, 2.5 km N Branchville, Saalman Hollow Nature Preserve, 38.1907, -86.5732, 12.III.2000, S.A. Grubbs and J.M. Ferguson, ♂, 1 nymph (WKUC); Mitchell Creek, 2 km SE Birdseye, Hoosier National Forest, 38.3006, -86.6599, 23.III.2006, S.A. Grubbs and R.E. DeWalt, 19♂, 11♀ (WKUC, INHS); Little Blue River, Rte. 37, 3 km N Sulphur, Hoosier National Forest, 38.2521, -86.4782, 23.III.2006, S.A. Grubbs and R.E. DeWalt, ♂ (WKUC); Dearborn Co., tributary to East Fork Tanners Creek, 11 km E Sunman, 39.2364, -84.9684, 20.III.2002, S.A. Grubbs, ♂ (WKUC); Dubois Co., small spring-fed stream, 7 km NE Ferdinand, Ferdinand State Forest, 38.2584, -86.7897, 6. IV.2001, S.A. Grubbs, 5♂, 4♀, 2 nymphs (WKUC); Franklin Co., Blue Creek, 7 km SSW Brookville, 39.3572, -85.0351, 20.III2002, S.A. Grubbs, 11♂, 8♀ (WKUC); creek at Mt. Carmel, Hwy 252, 28.III.1953, A.R. Gaufin, 35♂, 25♀ (BYUC); Jackson Co., Guthrie Creek, 18 km E Bedford, Hemlock Bluff Nature Preserve, 38.8492, -86.2615, 14.III.2000, S.A. Grubbs and J.M. Ferguson, 13♂, 4♀ (WKUC); tributary to Little Salt Creek, 7 km WSW Waymansville, Hoosier National Forest, 39.0030, -86.1968, 7.IV.2001, S.A. Grubbs, 8♂, 3♀ (WKUC); Jefferson Co., Little Doe Run, 12 km W Vevay, Splinter Ridge Fish and Wildlife Area, 38.7483, -85.2239, 20. III.2002, S.A. Grubbs, 7♂, 7♀ (WKUC); Monroe Co., tributary to Clear Creek, 3 km NW Herrodsburg, Cedar Bluffs Nature Preserve, 39.0364, -86.5636, 24.III.2006, R.E. DeWalt and S.A. Grubbs, 5♂, 2♀ (INHS, WKUC); Montgomery Co., Indian Creek, 8 km N Waveland, Pine Hills Nature Preserve, 39.9421, -87.0503, 9.IV.2006, R.E. DeWalt, 2♂, 3♀ (INHS); Ohio Co., tributary to Willow Creek, 5 km NW Enterprise, 38.9151, -85.0232, 20.III.2002, S.A. Grubbs, 6♂, 3♀ (WKUC); Parke Co., Rocky Hollow Creek, 6 km NNW Marshall, Rocky Hollow Falls Canyon Nature Preserve, 39.8952, -87.1990, 9.IV.2006, R.E. DeWalt, ♂, ♀ (INHS); Perry Co., East Deer Creek, 13 km E Tell City, Hoosier National Forest, 37.9508, -86.6144, 12. III.2000, S.A. Grubbs and J.M. Ferguson, 11♂, 2♀ (WKUC); tributary to East Deer Creek, 13 km E Tell City, Hoosier National Forest, 37.9506, -86.6140, 12.III.2000, S.A. Grubbs and J.M. Ferguson, 2♂, 3♀, 5 nymphs (WKUC); Pike Co., tributary to Patoka River, Rte.257, 1 km E Velpen, 38.3576, -87.0914, 8.IV.2000, S.A. Grubbs, ♂, 7♀ (WKUC); Putnam Co., tributary to Big Walnut Creek, 3 km ESE Bainbridge, Hall Woods Nature Preserve, 39.7579, -86.7807, 20.IV.2008, R.E. DeWalt and S.K. Ferguson, ♂ (INHS); Spencer Co., tributary to Anderson River, 11 km N Troy, 38.0891, -86.8018, 6.IV.2001, S.A. Grubbs, 2♂, 3♀ (WKUC). **Kansas:** Douglas Co., temporary stream, T12S, R20, S4¸10.V.1983, D.G. Huggins, ♂, 2♀ (BYUC). **Kentucky:** Cumberland Co., Marrowbone Creek, Leatherwood Rd. nr. Rte. 90, 6 km W Marrowbone, 36.8361, -85.5648, 27.III.2013, S.A. Grubbs and J.M. Yates, ♂, 4♀



Figures 3. *Zealeuctra claasseni*, scanning electron micrographs, USA, Indiana, Franklin Co., Blue Creek, 20 March 2002 (**A, E, I**), Kentucky, Monroe Co., Little Sulphur Creek, 18 March 2001 (**B, F, J**), Missouri, Hog Creek, 17 March 2002 (**C, G, K**) Oklahoma, West Cache Creek, 5 February 2003 (**D, H, L**). **A–D** male, cleft, dorsal view, 350× **E–H** male, epiproct, lateral view, 350× or 500× **I–L** female, posteromedial portion of seventh abdominal sternite, 200× or 350×.

(WKUC); Edmonson Co., Cub Creek, Rte. 70, 4 km W Roundhill, 37.2421, -86.3873, 30.III.2013, S.A. Grubbs, ♂, 2♀ (WKUC); tributary to Cub Creek, Rte. 70, 37.2397, -86.3961, 30.III.2013, S.A. Grubbs, 16♂, 7♀ (WKUC); Chenneth Branch, Shrewsbury Rd., 37.3709, -86.3473, 30.III.2013, S.A. Grubbs, 3♂, 3♀ (WKUC); Grayson Co., Buck Creek, KY 79 bridge SW of Caneyville, 37.4058,



Figures 3. Continued.

-86.5109, 22.II.1999, B.C. Kondratieff and R.F. Kirchner, ♂, ♀ (CSUC); Hancock Co., tributary to North Branch South Fork Panther Creek, Rte. 1700, 10 km N Fordsville, 37.7246, -86.6737, 16.III.2002, S.A. Grubbs, ♂, 4♀ (WKUC); Marion Co., Sulfur Lick Creek, 6 km SE New Hope at Sulfur Lick Rd., 37.5876, -85.4993, 11.IV.2009, R.E. DeWalt and E.T. Chabot, ♂, 5♀ (INHS); Metcalfe Co., East Fork Little Barren River, Delk Branch Road, 12 km N Marrowbone, 36.9387, -85.5075, 27.III.2013, S.A. Grubbs and J.M. Yates, 2♂, ♀ (WKUC); tributary to East Fork Little Barren River, Reese Hurt Road, 12.5 km N Marrowbone, 36.9457, -85.5188,

27.III.2013, S.A. Grubbs and J.M. Yates, 9♂, 3♀ (WKUC); tributary to Marrowbone Creek, Rte. 90, Marrowbone State Forest, 36.8487, -85.6081, 29.III.2009, S.A. Grubbs, ♂ (WKUC); same but 27.III.2013, S.A. Grubbs and J.M. Yates, ♂, ♀ (WKUC); Moccasin Creek, Glen Shaw Rd., 10.5 km NW Summer Shade, 36.9164, -85.5917, 27.III.2013, S.A. Grubbs and J.M. Yates, 3♂, 3♀ (WKUC). Monroe Co., Little Sulphur Creek, Rte. 100/214 junction, 9.5 km E Tompkinsville, 36.7057, -85.5932, 18.III.2001, S.A. Grubbs, 11♂, 6♀, nymph (WKUC); Ohio Co., tributary to Pond Run, Rte. 110, 6 km W Falls of Rough, 37.5870, -86.6143, 16.III.2002, S.A. Grubbs, 6♂, 5♀ (WKUC); Trigg Co., Elbow Creek, Land-Between-The-Lakes, 36.7698, -88.0350, 18.III.2000, S.A. Grubbs, ♂ (WKUC); Warren Co., Doty Creek, Hays-Pondsville Rd., 11 km SW Bon Ayr, 36.9782, -86.1577, 24.III.2001, S.A. Grubbs, 3♂, 5♀ (WKUC); small temporary stream, Beckham Rd., 11.5 km SW Bon Ayr, 36.9648, -86.1745, 24.III.2001, S.A. Grubbs, ♂, ♀ (WKUC). **Missouri:** Barry Co., East Fork Rock Creek, Hwy M N of Mano, 36.5947, -93.6988, 16.III.2004, B.C. Kondratieff, R.E. Zuellig, and M. Garhart, 10♂, 3♀ (CSUC); tributary to Roaring River, CR 1162, Chute Ridge, 36.5612, -93.7936, 16.III.2004, B.C. Kondratieff, R.E. Zuellig, and M. Garhart, 12♂, 8♀ (CSUC); tributary to Rock Creek, Hwy M N of Mano, 36.6100, -93.7008, 16.III.2004, B.C. Kondratieff, R.E. Zuellig, and M. Garhart, 3♂, 3♀ (CSUC); Ozark Co., Lick Creek, Hwy J N of Howards Ridge, 36.5502, -92.3437, 16.III.2002, B.C. Kondratieff and R.E. Zuellig, 10♂, 4♀(CSUC); Texas Co., West Fork Roubidoux Creek, Hwy M North of Huggins, 37.3534, -92.2091, 17.III.2002, B.C. Kondratieff and R.E. Zuellig, 38♂, 13♀(CSUC); Hog Creek, Lily Rd. S of Houston, 37.2400, -91.9527, 17.III.2002, B.C. Kondratieff and R.E. Zuellig, 42♂, 15♀(CSUC); Webster Co., Finley Creek, Hwy K S of Seymour, 37.1042, -92.7606, 17.III.2004, B.C. Kondratieff and R.E. Zuellig, 28♂, 15♀ (CSUC). **Ohio:** Clermont Co., stream, 2 mi W Neville, Rt. 52, 27.III.1974, O.S. Flint, 5♂, 6♀ (BYUC); Hocking Co., East Fork Salt Creek, Jct. OH 374/OH 56, 5.8 km ESE South Bloomingville, 39.3938, -82.5397, 18.IV.2010, R.E. DeWalt, ♂, 2♀ (INHS); Hoy Hollow Creek, 6.7 km E South Bloomingville, Hocking Hills State Park, 39.4236, -82.5221, 18.IV.2010, R.E. DeWalt, ♂, ♀(INHS); East Fork, Ash Cave, 39.3954, -82.5473, 21.III.1975, R.W. Baumann and O.S. Flint, 4♂, ♀ (BYUC), same but 14.IV.1990, Clark and Wells, ♂, 2♀ (BYUC); Logan Co., tributary to Macochee Creek, 1 mi S Pickrelltown, 40.2785, -83.6741, 21.IV.1989, R.W. Baumann and R.F. Kirchner, ♂, ♀ (BYUC); Ross Co., Ralston Run, Hwy 772 and Blain Hwy, 39.2413, -83.0597, 19.IV.1989, R.W. Baumann and R.F. Kirchner, 3♂, 3♀ (BYUC); Crooked Creek, Jct. Blain Hwy and Mt Tabor Rd., 39.2140, -83.0293, 19.IV.1989, R.W. Baumann and R.F. Kirchner, 2♂ (BYUC). **Oklahoma:** Comanche Co., Cedar Creek, Wichita Mountain National Wildlife Reserve, 34.7248, -98.6739, 4.I.2010, R.E. DeWalt and S.K. Ferguson, 13♂, 3♀ (INHS); West Cache Creek, border Wichita NWR, Fort Sill, W Hwy 115, 34.6814, -98.6644, 5.II.2003, B.C. Kondratieff, R.E. Zuellig, and J.P. Schmidt, 12♂, 7♀ (CSUC); tributary to Blue Beaver Creek, Deer Creek Rd. at Blue Beaver Valley Rd., 34.7000, -98.5653, 15.III.2004, B.C. Kondratieff, R.E. Zuellig, and M. Garhart, 6♂, 4♀ (CSUC); Medicine Creek, Punch Bowl

Rd., Fort Sill, 34.7169, -98.4903, 5.II.2003, B.C. Kondratieff, R.E. Zuellig, and J.P. Schmidt, 2♂, ♀ (CSUC); Blue Beaver Creek, McKenzie Hill Rd., Fort Sill, 34.6608, -98.5542, 5.II.2003, B.C. Kondratieff, R.E. Zuellig, and J.P. Schmidt, 25♂, 8♀ (CSUC); Johnston Co., Rock Creek, 5.8 km SE Mill Creek at OK 7, 34.3612, -96.7887, 3.I.2010, R.E. DeWalt and S.K. Ferguson, 4♂ (INHS); Latimer Co., Rock Creek, CR NE1130, 35.0186, -95.0599, 27.XII.2006, B.P. Stark, 3♂, 2♀ (BPSC).

Distribution. USA: AL, AR, IL, IN, KS, KY, MO, OK, OH, TN, TX, WV (DeWalt et al. 2012)

Remarks. Despite the broad distribution (Fig. 12), there appears to the little variation in the general features of the cleft. Only a minor degree of variation is evident in the epiproct, particular in the size and shape of the triangular base. Ricker and Ross (1969, their fig. 20) and Poulton and Stewart (1991, their fig. 112) depicted an epiproct base that is markedly broader than what is shown here with SEM micrographs.

***Zealeuctra fraxina* Ricker & Ross**
http://species-id.net/wiki/Zealeuctra_fraxina
Figs 4, 11

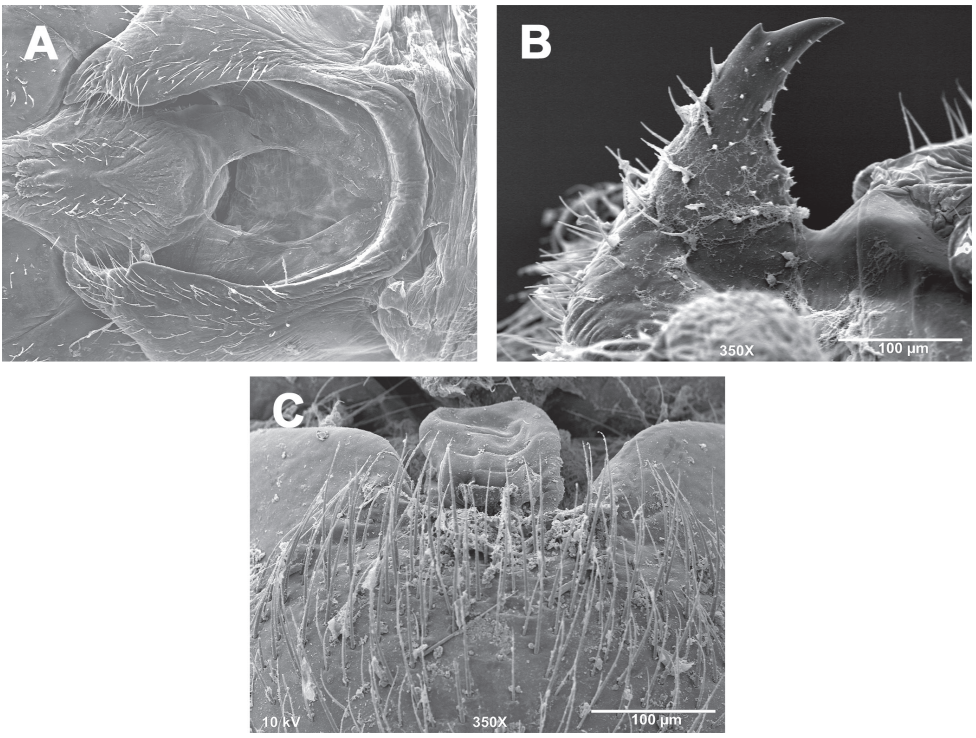
Zealeuctra fraxina Ricker & Ross, 1969: 1117. Holotype ♂ (INHS), 5 mi S Hardinsburg, Breckinridge Co., Kentucky

Description. Male - abdominal tergal cleft. Anterior portion wide and very broadly U-shaped, posterior portion also broadly rounded and bearing a slightly-concave serrated medial projection (Fig. 4A). Crenulations absent from inner margins of cleft.

Male - epiproct. Triangular base narrowing somewhat to an anteriorly-recurved and tapering terminal spine; a small accessory posterior spine is present but manifested only as a cusp-like projection on some specimens (Fig. 4B).

Female - 7th sternum. Seventh sternum with a large, convex lobe nested in a distinct, central notch. The notch is bordered laterally by large, convex "shoulders" (Fig. 4C).

Material examined. USA, **Alabama:** Jackson Co., tributary to Larkin Fork, Paint Rock River, Possum Hollow, Rte. 65, 1 km SE Francisco, 34.9852, -86.2421, 18.II.2006, S.A. Grubbs, 4♂, 12♀ (WKUC); Lawrence Co., tributary to West Fork Flint Creek, CR 56, 18 km NNW Addison, 34.3679, -87.1794, 7.II.2009, S.A. Grubbs, 2♂ (WKUC). **Illinois:** Saline Co., Battle Ford Creek, 3.5 km NE Delwood, 37.6050, -88.5440, 20.I.1993, D.W. Webb and M.A. Harris, ♂ (INHS). **Indiana:** Brown Co., Spanker Branch, 14 km S Nashville, 39.0700, -86.2623, 7.IV.2001, S.A. Grubbs, ♂, 4♀ (WKUC); Skinner Creek, 8 km SSE Nashville, Brown County State Park, 39.1395, -86.2066, 7.IV.2001, S.A. Grubbs, ♂ (WKUC); Crawford Co., small spring-fed stream, Rich Cave Hollow, Saalman Hollow Nature Preserve, 2.5 km N Branchville, 38.1907, -86.5732, 12.III.2000, S.A. Grubbs and J.M. Ferguson, 4♂, 4♀, 1 nymph (WKUC); tributary to Otter Creek, 1 km SE Taswell, Yellow Birches Ravine Nature Preserve, 38.3255, -86.5491, 14.III.2000, S.A. Grubbs and



Figures 4. *Zealeuctra fraxina*, scanning electron micrographs, USA, Alabama, Jackson Co., tributary to Larkin Fork, Paint Rock River, 18 February 2006 (**A–B**), USA, Indiana, Martin Co., tributary to Lost River, 6 April 2001 (**C**). **A** male, cleft, dorsal view, 200× **B** male, epiproct, lateral view, 350× **C** female, posteromedial portion of seventh abdominal sternite, 350×.

J.M. Ferguson, ♂ (WKUC); Floyd Co., tributary to Knob Creek, 17 km E Corydon, Brock-Sampson Nature Preserve, 38.1975, -85.9040, 13.III.2000, S.A. Grubbs and J.M. Ferguson, ♂, 3♀ (WKUC); Franklin Co., Salt Creek, 2 km W Peppertown at Bull Fork Rd., 39.4033, -85.2061, 4.II.2010, R.E. DeWalt and M. Pessino, 2♂, ♀ (INHS); West Fork Whitewater River, 1.4 km W Metamora at U.S. 52, 39.4507, -85.1495, 4.II.2010, R.E. DeWalt and M. Pessino, ♂, 3♀ (INHS); Harrison Co., tributary to Potato Run, 6 km E Leavenworth, Harrison-Crawford State Forest, 38.1876, -86.2766, 12.III.2000, S.A. Grubbs and J.M. Ferguson, 11♂, 12♀ (WKUC); Jackson Co., Combs Branch, 2.5 km NW Maumee at Tower Ridge Rd., 39.0316, -86.2832, 12.III.2010, M. Pessino, ♂, 3♀ (INHS). Lawrence Co., Sipes Branch, 4.5 km ENE Bartlettsville at Martin Hollow Rd, 38.9825, -86.3914, 12.III.2010, M. Pessino, 2♂, ♀ (INHS). Martin Co., tributary to Lost River, U.S. 150, 4 km SE Shoals, 38.6315, -86.7691, 6.IV.2001, S.A. Grubbs, 2♂, 9♀ (WKUC). Monroe Co., Allens Creek, 8 km SE Smithville, 39.0210, -86.4375, 14.III.2010, R.E. DeWalt and M. Pessino, ♂ (INHS). Orange Co., spring into Young's Creek, 8 km S Paoli, 38.4903, - 86.4459, 20.II.2006, S.A. Grubbs, 2♂ (WKUC); Perry Co., East Deer Creek, 13 km E Tell

City, Hoosier National Forest, 37.9508, -86.6144, 12.III.2000, S.A. Grubbs and J.M. Ferguson, 2♂, ♀ (WKUC); Scott Co., tributary to Big Ox Creek, 14 km SW Scottsburg, Clark State Forest, 38.5787, -85.8703, 15.III.2000, S.A. Grubbs and J.M. Ferguson, ♂ (WKUC). **Kentucky:** Cumberland Co., tributary to Bear Creek, Rte. 90, 15 km NW Albany, 36.7680, -85.2847, 18.III.2001, S.A. Grubbs, 6♂, ♀ (WKUC); Metcalfe Co., East Fork Little Barren River, Delk Branch Road, 12 km N Marrowbone, 36.9387, -85.5075, 27.III.2013, S.A. Grubbs and J.M. Yates, 2♂, ♀ (WKUC); tributary to East Fork Little Barren River, Reese Hurt Road, 12.5 km N Marrowbone, 36.9457, -85.5188, 27.III.2013, S.A. Grubbs and J.M. Yates, ♂, 3♀ (WKUC). **Ohio:** Lawrence Co., tributary to Storms Creek, 12 km SW Waterloo, Wayne National Forest, 38.6313, -82.5810, 26.II.2011, S.A. Grubbs, ♀ (WKUC). **Tennessee:** Sumner Co., tributary to Bledsoe Creek, Leaths Hollow Church Rd., 36.5153, -86.2437, 23.II.1998, B.C. Kondratieff and R.F. Kirchner, ♂ (CSUC); tributary to Little Trammel Creek, Sugar Grove, 36.6239, -86.2679, 22.II.1999, B.C. Kondratieff and R.F. Kirchner, 8♂, 8♀ (BPSC, BYUC); Little Trammel Creek, Rte. 174, nr. Sugar Grove, 36.6239, -86.2679, 18.I.2010, S.A. Grubbs, 2♂ (WKUC). **Virginia:** Bedford Co., Peaks of Otter Lake, 37.4454, -79.6029, 12.III.2013, E.M. Malloy, ♂ (WKUC).

Distribution. USA: AL (Grubbs 2006), IL, IN, KY, NJ, OH, PA, TN, WV (DeWalt et al. 2012), VA (new state record)

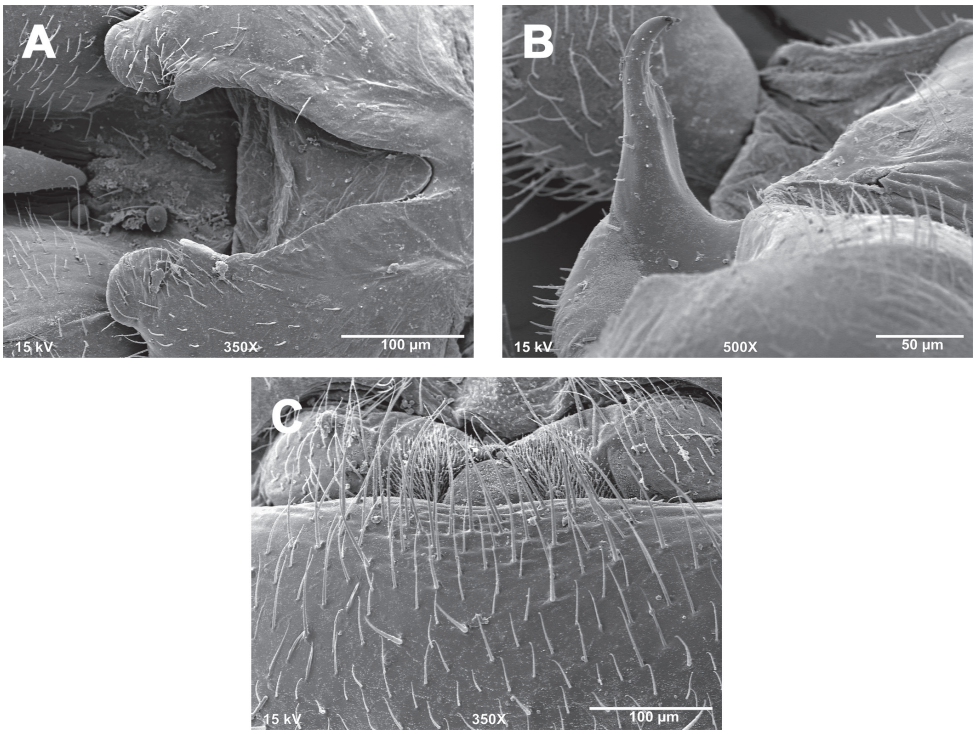
Remarks. Only *Z. claasseni* is distributed more broadly across the central and eastern US than *Z. fraxina* (Fig. 11; DeWalt et al. 2012). Additionally, this is one of only two species, *Z. talladega* being the other, that occur in the Appalachian Mountains. The Virginia record noted above was collected along the margins of Peaks of Otter Lake, but surprisingly several hundred meters from the nearest inlet or the only outlet (Little Stony Creek). *Zealeuctra fraxina* and *Z. arnoldi* are the only two species that bear a small subterminal cusp posterior to the tapering epiproct spine. Ricker and Ross (1969, their fig. 28) speculated that these two species, plus *Z. wachita*, share a common ancestor.

Zealeuctra hitei **Ricker & Ross**

http://species-id.net/wiki/Zealeuctra_hitei
Figs 5, 11

Zealeuctra hitei Ricker & Ross, 1969: 1118. Holotype ♂ (INHS), 3 mi S Johnson City, Blanco Co., Texas

Description. Male - abdominal tergal cleft. Anterior portion nearly identical to *Z. claasseni*, with slight inward medial swelling but no apparent crenulations along inner margins (Fig. 5A). Posterior portion slightly more U-shaped with paired medially-projected processes, the terminal projection larger, convex, and thumb-like, the subterminal projection smaller and subtriangular.



Figures 5. *Zealeuctra hitei*, scanning electron micrographs, USA, Texas, Kimble Co., Sycamore Creek, 14 December 1989. **A** male, cleft, dorsal view, 350× **B** male, epiproct, lateral view, 500× **C** female, posteromedial portion of seventh abdominal sternite, 350×.

Male - epiproct. Base slender and triangular, narrowing to anteriorly-recurved and tapering terminal spine, no accessory spine present (Fig. 5B). A small "step" (sensu Ricker and Ross 1969) demarks the base from the tapering spine. No accessory spine or cusp present.

Female - 7th sternum. Seventh sternum with a small, subtriangular lobe nested in a scarcely-concave central notch (Fig. 5C). Posterior margin essentially straight.

Material examined. USA, **Texas:** Coryell Co., Cowhouse Creek, Hwy 116 N of Copperas Cove, 31.2861, -97.8840, 21.XII.1969, K.W. Stewart, 2♂, ♀ (BPSC); Gillespie Co., stream at base of Summit Trail, Enchanted Rock State Natural Area, 30.4964,-98.8214, 19.I.1998, C.R. Nelson, 62♂, 23♀ (BYUC); Hays Co., Barton Creek, Hwy 12, N of Dripping Springs, 30.2380, -98.0665, 14.III.1993, R.W. Baumann and B.C. Kondratieff, ♂, ♀ (BYUC); small creek, 123 Rabbit Road, 11.IV.1992, S. Stringer, 2♂, ♀ (BYUC); Kimble Co., Sycamore Creek, Segovia, 30.4225, -99.6671, 14.XII.1989, B.C. Kondratieff and J.L. Welch, 3♂, 7♀ (CSUC); Travis Co., Barton Creek, Austin, near jct Lost Creek Blvd, 30.2739,-97.8449, 6.III.1997, C.R. Nelson, 2, 3 (BYUC).

Distribution. USA: TX (DeWalt et al. 2012)

Remarks. The form of the cleft of this species is nearly identical to *Z. claasseni*, and the epiproct is essentially a narrower form of that exhibited by *Z. claasseni*. Ricker and Ross (1969, their fig. 28) speculated that these two species share a common ancestor.

***Zealeuctra narfi* Ricker & Ross**
http://species-id.net/wiki/Zealeuctra_narfi
Fig. 6, 14

Zealeuctra narfi Ricker & Ross, 1969: 1118. Holotype ♂ (INHS), Otter Creek, Sauk Co., Wisconsin

Description. Male - abdominal tergal cleft. Anterior portion U-shaped and tapering slightly to a broadly-rounded anterior terminus (Fig. 6A). Posterior portion markedly narrower than anterior portion, with a pair of medially-projected processes (Figs 6A–B), the terminal projection larger, subtruncate, and thumb-like, the subterminal projection smaller and subtriangular.

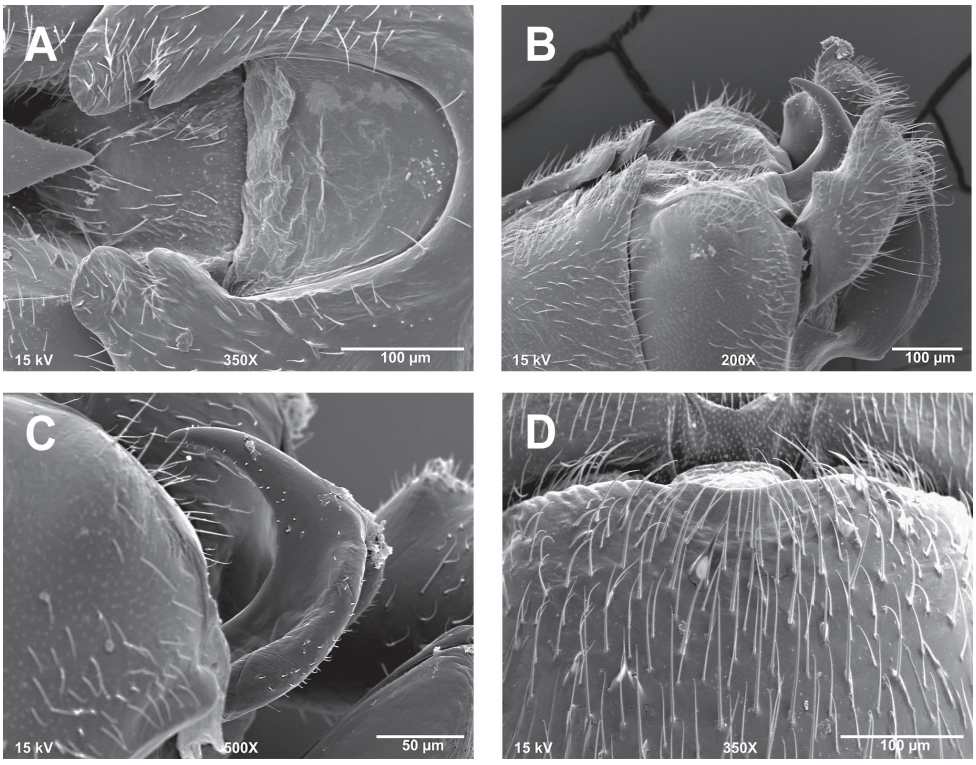
Male - epiproct. Base broad and slightly-directed posterodorsally, tip of spine directed abruptly and anteriorly at ca. 90° angle from base, tapering and gently recurved anteriorly (Figs 6B–C). No accessory spine or cusp present.

Female - 7th sternum. Seventh sternum with a broadly-subquadrate lobe nested in a scarcely-convex central notch (Fig. 6D). Posterior margins essentially straight.

Material examined. USA, **Arkansas:** Pope Co., tributary to Little Creek, 4 mi NW Scottsville, 35.4776, -93.0836, 6.I.1985, B.C. Poulton, ♂ (BPSC); Sharp Co., unnamed creek, Cherokee Village, 36.2999,-91.5158, 4.III.1978, McGraw, 3♂ (CSUC); White Co., tributary to Little Cypress Creek, Hwy 5 at El Paso, 35.1264, -92.0974, 17.III.1984, B.C. Poulton, 2♂ (CSUC); Yell Co., 3 mi N Onyx, Hwy 27, 34.8899, -93.3937, 6.I.1999, B.P. Stark 2♂, 2♀ (BPSC). **Illinois:** Pope Co., tributary to Burden Branch, below Burden Falls, Shawnee National Forest, 37.5641, -88.6434, 3.IV.2013, S.A. Grubbs and J.M. Yates, 4♂, 12♀ (WKUC); tributary to Burden Branch, Shawnee National Forest, 37.5641, -88.6387, 3.IV.2013, S.A. Grubbs and J.M. Yates, 9♂, 12♀ (WKUC); Saline Co., Battle Ford Creek, 3.5 km NE Delwood, 37.6050, -88.5440, 26.II.1992, D.W. Webb and M.A. Harris, ♂ (INHS). **Missouri:** Barry Co., tributary to Rock Creek, Hwy M N of Mano (Big M), 36.6100, -93.7008, 16.III.2004, B.C. Kondratieff, R.E. Zuellig, and M. Garhart, 10♂, 8♀ (BYUC, CSUC); tributary to Roaring River, CR 1162, Chute Ridge, 36.5612, -93.7936, 16.III.2004, B.C. Kondratieff, R.E. Zuellig, and M. Garhart, 28♂, 13♀ (CSUC); East Fork Rock Creek, Hwy M N Mano, 36.5947, -93.6988, 16.III.2004, B.C. Kondratieff, R.E. Zuellig, and M. Garhart, 46♂, 19♀ (CSUC); Stone Co., creek with old dam, Million Oaks sub tract, Table Rock Reservoir, 17.III.1993, S. Fitzgerald, 35♂, 9♀(CSUC).

Distribution. USA: AR, IL, MO, OK, WI (DeWalt et al. 2012)

Remarks. Although the type locality for *Z. narfi* is in southern Wisconsin, this species is common and widespread only in the southern portion of its range, and par-



Figures 6. *Zealeuctra narfi*, scanning electron micrographs, USA, Missouri, Barry Co., East Fork Rock Creek, 16 March 2004. **A** male, cleft, dorsal view, 350×(**B** male, abdominal terminalia, lateral view, 200× **C** male, epiproct, lateral view, 500× **D** female, posteromedial portion of seventh abdominal sternite, 350×.

ticularly in southern Missouri (Fig. 14). There are only three known locations for *Z. narfi* in Wisconsin (DeWalt unpublished data) and is likewise uncommon in Illinois, with only three collected localities between 1976 and 2000 (Webb 2002). There have also been several failed attempts by the senior author to locate this species in western and southern Indiana.

Zealeuctra stewarti Kondratieff & Zuellig

http://species-id.net/wiki/Zealeuctra_stewarti
Fig. 13

Zealeuctra stewarti Kondratieff & Zuellig, 2004: 840. Holotype ♂ (TAMU), 5.2 mi E Leakey, Real Co., Texas

Description. Male - abdominal tergal cleft. Anterior portion broadly U-shaped and parallel-sided. Posterior portion V-shaped, with small crenulations evident along inner

margins, terminating posteriorly with paired, subtriangular, medially-projected extensions (Kondratieff and Zuellig 2004, their Fig. 1)

Male - epiproct. Epiproct spine long, slender, and gently-recurved anteriorly (Kondratieff and Zuellig 2004; their fig. 2). No accessory spine or cusp present.

Female - 7th sternum. Seventh sternum lacking medial lobe, with posteromedial portion overlapping as a slightly-notched, subtruncate flap onto anteromedial margin of the eighth sternum Kondratieff and Zuellig 2004; their fig. 3).

Material examined. USA, **Texas:** Real Co., Little Dry Frio, Farm Rd. 337 E of Leakey, 29.7214, -99.6739, 3.IV.2004, B.C. Kondratieff and R.E. Zuellig, 4♂, 6♀ (Paratypes; BYUC, CSUC); Little Dry Frio, Hwy 337, 5.2 mi E of Leakey, 29.7214, -99.6739, 20.II.2010, K.W. Stewart, 2♂ (BPSC).

Distribution. USA: TX (DeWalt et al. 2012)

Remarks. This is easily the rarest of the *Zealeuctra* species, currently known only from two streams within a very small geographic area in the Texas Hill Country region (Fig. 13; Kondratieff and Zuellig 2004), overlapping in range and adult flight periods only with *Z. arnoldi.* The long and very slender epiproct spine exhibited by *Z. stewarti* is unique and easily distinguished from all members of this genus. In addition, the females of *Z. stewarti* and *Z. warreni* are the only two *Zealeuctra* species lacking a posterior lobe nested in central notch and where the posteromedial portion of the 7th sternum is flap-like and extending over the anteromedial margin of the 8th sternum.

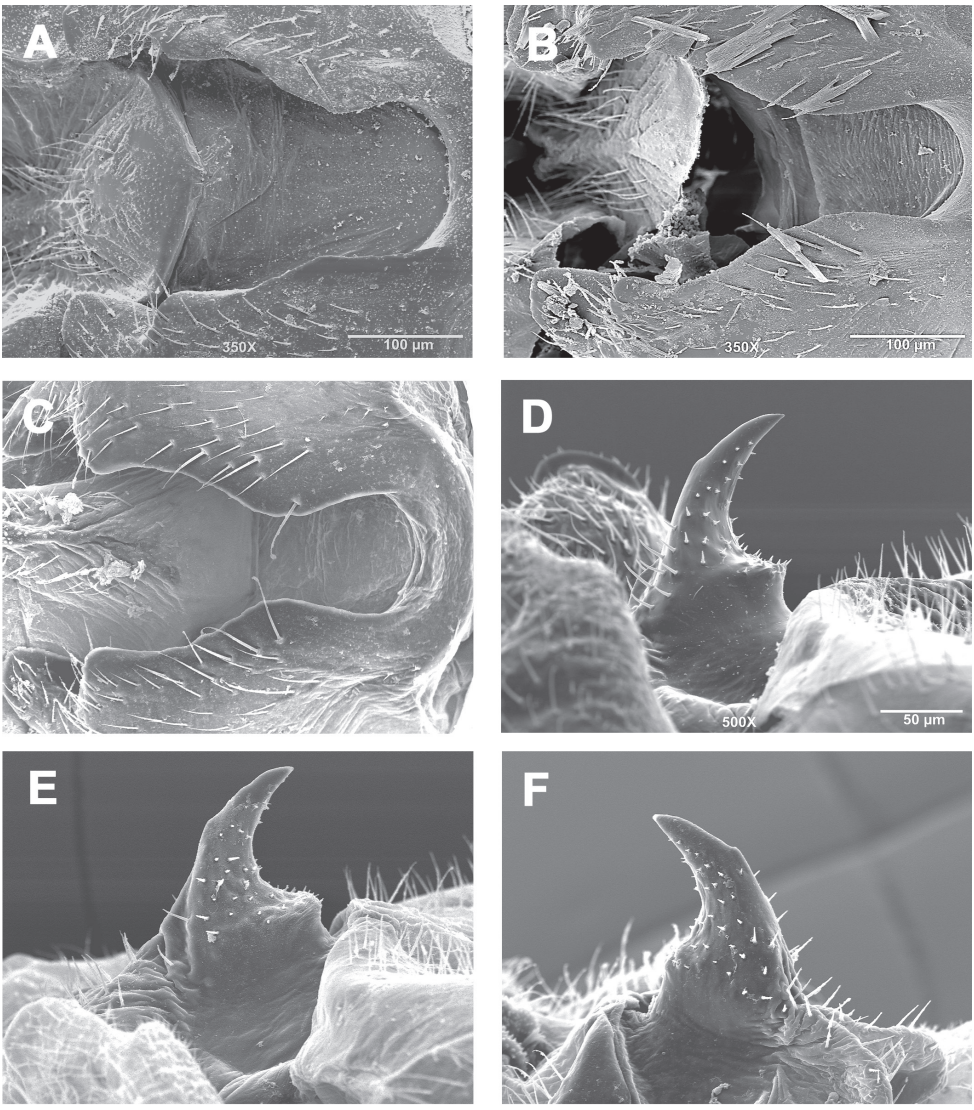
***Zealeuctra talladega* Grubbs**
http://species-id.net/wiki/Zealeuctra_talladega
Figs 7, 13

Zealeuctra talladega Grubbs, 2005: 40. Holotype ♂ (INHS), tributary to Barbaree Creek, 22 km E Talladega, Clay Co., Alabama

Description. Male - abdominal tergal cleft. Anterior portion is near parallel-sided, U-shaped, and broadly rounded along anterior margin (Figs 7A–C). Posterior portion is somewhat V-shaped and sinuous along inner margins, posterior terminus marked by either a single (Fig. 7C) or paired (Figs 7A–8B) medially-directed subtriangular projections. Crenulations absent from inner margins of cleft..

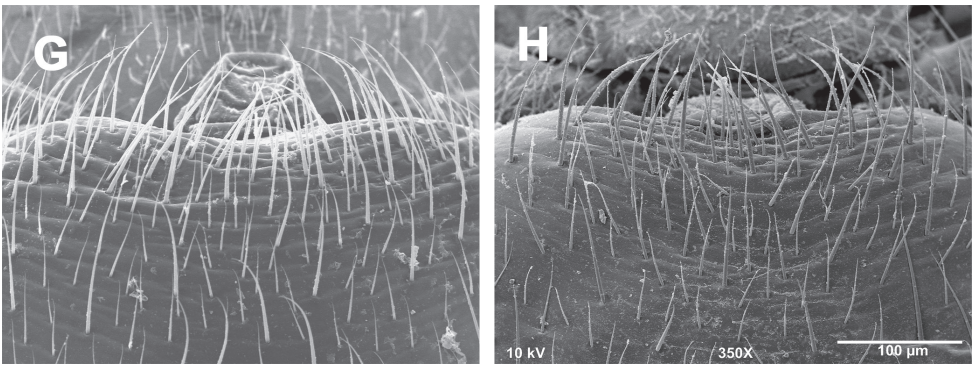
Male - epiproct. Base very broad and subquadrate in shape, narrowing to anteriorly-recurved and broadly tapering terminal spine, no accessory spine present although a small subterminal posterior nub may be present (Figs 7D–F). Subquadrate base varies from rounded broadly to right angular in shape. No accessory spine or cusp present, but a minute, very low, medially-positioned hump is present along the anterior, recurved portion of epiproct (Figs 7D–F).

Female - 7th sternum. Seventh sternum with a small, lobe nested in a scarcely-convex central notch. Lobe ranges in shape from subtriangular (Fig. 7G) to convex (Fig. 7H). Posterior margin moderately convex.



Figures 7. *Zealeuctra talladega*, scanning electron micrographs, USA, Alabama, Clay Co., tributary to Swept Creek, 24 January 2006 (**A–B, D–E, G**), USA, Alabama, Clay Co., tributary to West Fork Hatchet Creek, 25 January 2006 (**C, F, H**). **A–C** male, cleft, dorsal view, 350× **D–F** male, epiproct, lateral view, 500× **G–H** female, posteromedial portion of seventh abdominal sternite, 350×.

Material examined. USA, **Alabama:** Clay Co., tributary to Barbaree Creek, 22 km E Talladega, Talladega National Forest, 33.4187, -85.8706, 16.II.2003, S.A. Grubbs and D.K. King, 2♂, 2♀ (WKUC – paratypes); same but 5.III.2012, S.A. Grubbs, ♂, 4♀ (WKUC); Swept Creek, Talladega National Forest, 33.2602, -86.1006, 23.I.2006, A.L. Sheldon, ♀ (WKUC); tributary to Swept Creek, Talladega National Forest, 33.2595, -86.1031, 23.I.2006, A.L. Sheldon, 3♂, 6♀ (WKUC);



Figures 7. Continued

tributary to Swept Creek, Talladega National Forest, 33.2632, -86.0922, 24.I.2006, A.L. Sheldon, 7♂, 9♀ (WKUC); South Branch Swept Creek, Talladega National Forest, 33.2607, -86.0952, 24.I.2006, A.L. Sheldon, 2♂, 6♀ (WKUC); tributary to Swept Creek, Talladega National Forest, 33.2614, -86.0955, 24.I.2006, A.L. Sheldon, ♀ (WKUC); tributary to West Fork Hatchet Creek, Talladega National Forest, Forest, 33.2938, -86.0780, 25.I.2006, A.L. Sheldon, ♂ (WKUC); tributary to West Fork Hatchet Creek, Talladega National Forest, Forest, 33.2740, -86.0733, 25.I.2006, A.L. Sheldon, ♂, ♀ (WKUC); tributary to West Fork Hatchet Creek, Talladega National Forest, Forest, 33.2823, -86.0666, 25.I.2006, A.L. Sheldon, 4♂, 4♀ (WKUC); tributary to West Fork Hatchet Creek, Talladega National Forest, 33.2825, -86.0668, 8.III.2007, A.L. Sheldon, 3♀ (WKUC); tributary to West Fork Hatchet Creek, Talladega National Forest, 33.2743, -86.0739, 8.III.2007, A.L. Sheldon, 2♀ (WKUC); tributary to West Fork Hatchet Creek, Talladega National Forest, 33.3219, -86.0671, 7.IV.2008, A.L. Sheldon, 2♀ (WKUC); tributary to West Fork Hatchet Creek, FR 662, 16 km SSE Talladega, Talladega National Forest, 33.3048, -86.0380, 5.III.2012, S.A. Grubbs, ♂, 2♀ (WKUC); tributary to Hatchet Creek, FR 687, Talladega National Forest, 33.1557, -86.1196, 5.III.2012, S.A. Grubbs, 4♀ (WKUC); tributary to Cheaha Creek, Talladega National Forest, 33.4397, -85.8387, 5.III.2012, S.A. Grubbs, ♀ (WKUC); tributary to Tallaseehatchie Creek, FR 616, Talladega National Forest, 33.2053, -86.0800, 5.III.2012, S.A. Grubbs, ♂, 2♀ (WKUC); Cleburne Co., Cheaha Creek, above Cheaha Lake, Cheaha State Park, 2.III.1991, R.W. Baumann and S.M. Clark, 2♂, 2♀ (BYUC); Talladega Co., tributary to Smelley Creek, Talladega National Forest, 33.2988, -86.0842, 8.III.2007, A.L. Sheldon, ♂, 6♀ (WKUC), Smelley Creek, Talladega National Forest, 33.3010, -86.0945, 21.XII.2007, A.L. Sheldon, ♂ (WKUC); tributary to Smelley Creek, Talladega National Forest, 33.3006, -86.0862, 7.IV.2008, A.L. Sheldon, ♂, 2♀ (WKUC).

Distribution. USA: AL (DeWalt et al. 2012)

Remarks. This species is known only from the southern Talladega Mountains region of eastern Alabama (Fig. 13), the southern terminus of the Appalachian Moun-

tains. Extensive collecting efforts by both the author and Dr. Andrew Sheldon since 2005 have yet to produce localities north from the two counties (Clay and Talladega) where this species has been obtained.

***Zealeuctra ukayodi* Grubbs, sp. n.**
http://zoobank.org/7D5A6F56-AA11-458D-868B-CB7654BFD8C8
http://species-id.net/wiki/Zealeuctra_ukayodi
Figs 8, 13

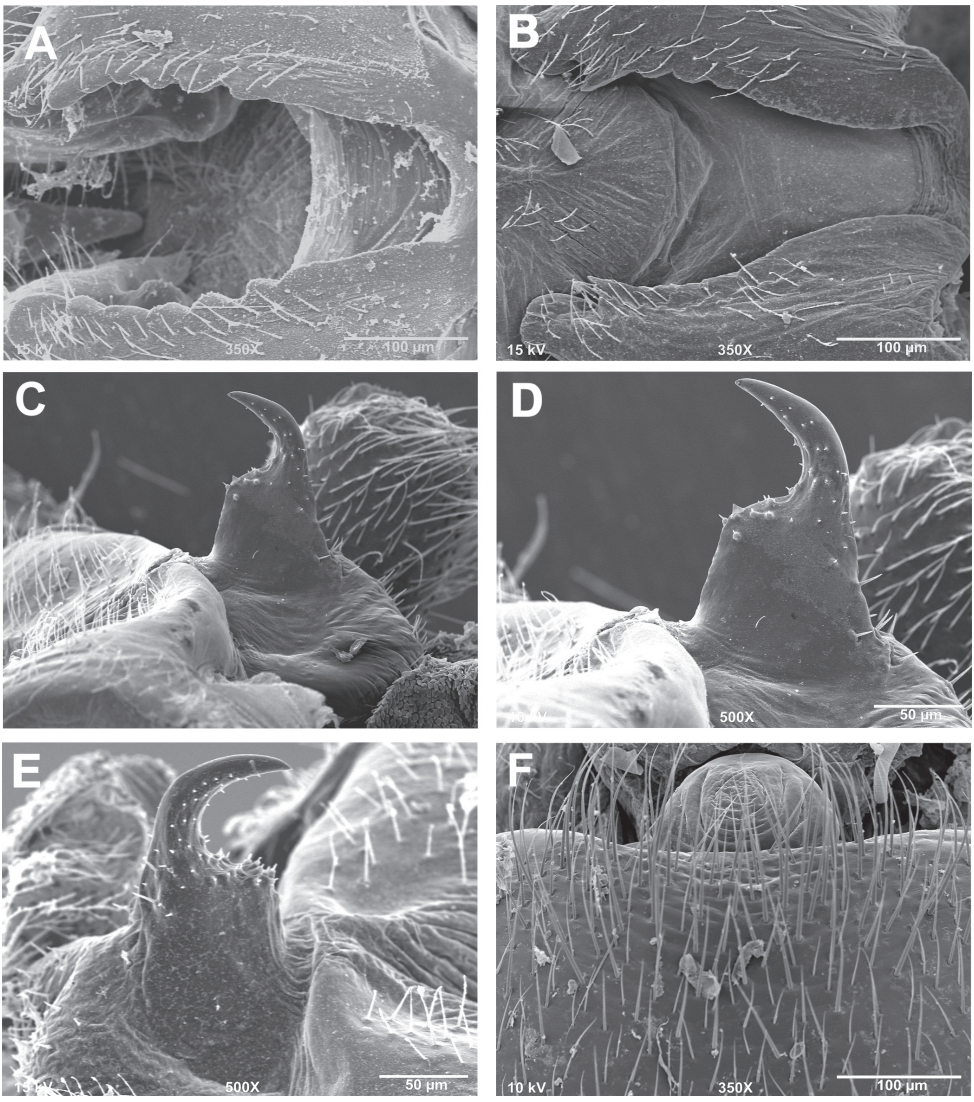
Description. Male. Forewing length 6.5–7.0 mm; body length 5.0–5.5 mm. General body color brown.

Anterior portion of male abdominal tergal cleft is narrowly U-shaped, and rounded along the anterior terminus. The posterior portion is widest anteriorly with crenulations present along inner margins. Overall shape of cleft ranges from either V-shaped to somewhat sinuous (Figs 8A–B, I). Epiproct base very broad and subquadrate in shape, narrowing to anteriorly-recurved and broadly tapering terminal spine, no accessory spine present (Figs 8C–E). Subquadrate base varies in from rounded broadly to right angular in shape. No accessory spine or cusp present. Cerci sclerotized mainly along outer margin and bearing a small dorsomedial hump and a subapical, triangular sclerotized tooth (Figs 8G–I). Length of vesicle ca. 1.5× width.

Female. Forewing length 7.5–8.0 mm; body length 6.0–8.0 mm. General body color brown. Seventh sternum with a quadrate sclerotized region, convex posteriorly, and scarcely projecting over the anterior portion of the eighth sternum (Fig. 8I); posteromedial portion unpigmented and very slightly notched, bearing a lightly-pigmented lobe that is convex posteriorly (Figs 8F, I).

Nymph. Unknown.

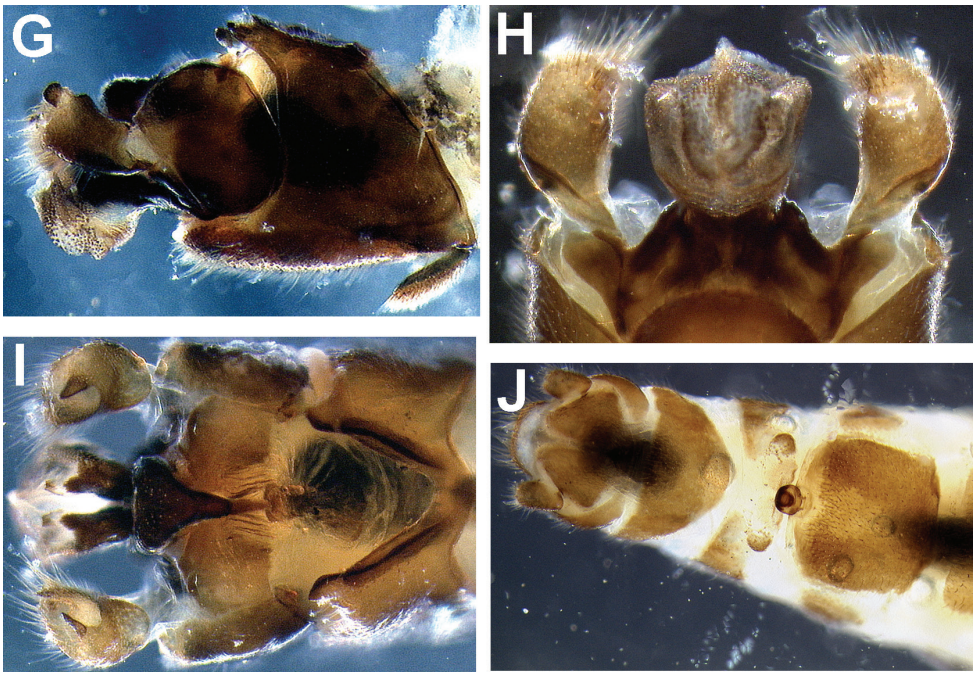
Material examined. Holotype ♂, in 95% ethyl alcohol, **USA**, **Alabama**, Jackson Co., Poplar Spring, 6 km SW Hytop, 34.8779, -86.1283, 19.II.2007, S.A. Grubbs (INHS). Paratypes: same as Holotype, 19.II.2007, S.A. Grubbs, 4♂, 7♀ (WKUC); same as Holotype but 16.III.2008, S.A. Grubbs, 13♂, 30♀ (INHS, WKUC). **Tennessee:** Cumberland Co., North Fork Elmore Creek, TN Rte. 298, 36.1037, -84.9414, 9.II.1998, B.C. Kondratieff and R.F. Kirchner, 2♂, 4♀ (CSUC); Grundy Co., tributary to Elk River, Rte. 50, 14 km N Monteagle, 35.3578, -85.8363, 12.II.2007, S.A. Grubbs, ♂, 2♀ (WKUC); Marion Co., tributary to Cross Creek, 17 km NW South Pittsburg, Franklin-Marion State Forest, 35.0847, -85.8673, 12.II.2007, S.A. Grubbs, ♂ (WKUC); tributary to Sweeten Creek, 15 km NW South Pittsburg, Franklin-Marion State Forest, 35.0827, -85.8391, 12.II.2007, S.A. Grubbs, 2♀ (WKUC); tributary to Sweeten Creek, 15 km NW South Pittsburg, Franklin-Marion State Forest, 35.0942, -85.8600, 8.II.2013, S.A. Grubbs, 3♂, 17♀ (WKUC); Cave Springs Creek, Franklin-Marion State Forest, 35.0764, -85.8427, 25.II.2007, A.L. Sheldon, ♂, ♀ (WKUC).



Figures 8. *Zealeuctra ukayodi*, sp. n., scanning electron micrographs, USA, Alabama, Jackson Co., Poplar Spring, 16 March 2008 (**A–D, F–J**), USA, Tennessee, Grundy Co., tributary to Elk River, 12 February 2007 (**E**). **A–B** male, cleft, dorsal view, 200× **C–E** male, epiproct, lateral view, 350× or 500× **F** female, posteromedial portion of seventh abdominal sternite, 350× **G** male terminalia, lateral **H** male terminalia, dorsal **I** male terminalia, ventral **J** female terminalia, ventral.

Etymology. The specific epithet is a Cherokee word for "dry", a figurative reference to the temporary stream habitat characteristic of this species. Cherokee Native Americans formerly inhabited the southern Cumberland Plateau region.

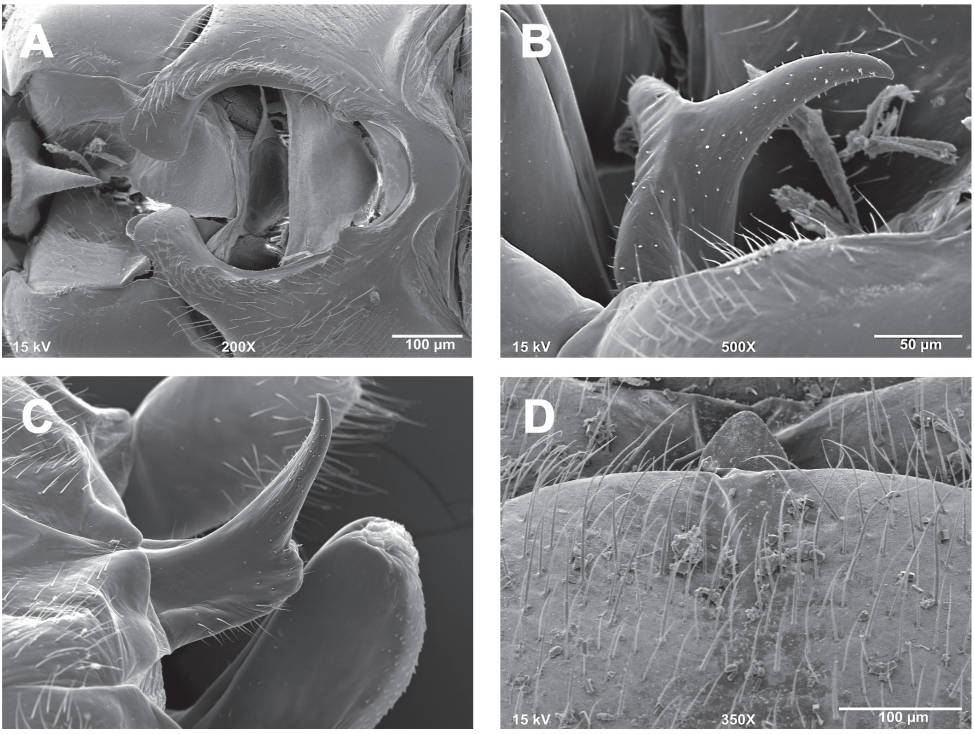
Diagnosis. The species is similar only to the cognate *Z. talladega*, and these two species can be separated mainly by characteristics of the male cleft. In *Z. talladega*, the



Figures 8. Continued.

cleft is highly sinuous or hourglass in shape and lacks the large crenulations along the inner margins. In *Z. ukayodi*, the cleft ranges from broadly V-shaped to somewhat sinuous, with large, conspicuous crenulations present along the inner margins of the posterior portion. Variation in the shape of the epiproct, namely the anterior quadrate or subquadrate shelf, overlaps between the two species. There is also a minute, medially-positioned hump present along the anterior, recurved portion of epiproct in *Z. talladega* (Figs 7D–F) that is lacking entirely in *Z. ukayodi* (Figs 8C–E). The fused subanal plates-anal probe of *Z. talladega* and *Z. ukayodi* appears to be highly similar in structure.

Remarks. *Zealeuctra ukayodi* appears to be restricted to the southern portion of the Cumberland Plateau, known at present from central Tennessee south to the type locality in northeastern Alabama (Fig. 13). The range of only one other *Zealeuctra* species, *Z. fraxina*, extends south and eastward into the Cumberland Plateau region in northeastern Alabama (Grubbs 2006). No other stonefly species have been collected at the type locality. *Allocapnia unzickeri* Ross & Yamamoto, *Oemopteryx contorta* (Needham & Claassen), and *Taeniopteryx ugola* Ricker & Ross have been obtained with *Z. ukayodi* at some of the paratype localities in Tennessee. The common name, Cumberland Needlefly, is proposed for this species (Stark et al. 2012).



Figures 9. *Zealeuctra wachita*, scanning electron micrographs, USA, Oklahoma, LeFlore Co., tributary to Big Creek, 6 February 2003 (**A, B, D**), USA, Arkansas, Scott Co., Johnson Creek, 6 January 1999 (**C**). **A** male, cleft, dorsal view, 200× **B–C** male, epiproct, lateral view, 350× or 500× **D** female, posteromedial portion of seventh abdominal sternite, 350×.

***Zealeuctra wachita* Ricker & Ross**
http://species-id.net/wiki/Zealeuctra_wachita
Figs 9, 11

Zealeuctra wachita Ricker & Ross, 1969: 1119. Holotype ♂ (INHS), Ouachita River, Polk Co., Arkansas

Description. Male - abdominal tergal cleft. Anterior portion broadly rounded, with a secondary U-shaped extension, inner margins set apart from remainder of cleft (Fig. 9A). Posterior portion markedly wider than anterior portion, interior margins rounded and lacking crenulations, terminating posteriorly as paired, large subtruncate medially-projected extensions.

Male - epiproct. Base narrow and extending laterally (Fig. 9A), spine directed at ca. 90° angle from base, tapering gradually, and recurved somewhat anteriorly (Figs 9B–C). No accessory spine or cusp present.

Female - 7th sternum. Seventh sternum with a small, subtriangular lobe nested in a slightly-concave central notch (Fig. 9D).

Material examined. USA, **Arkansas:** Scott Co., Johnson Creek, Hwy 49, 34.7131, -94.2101, 6.I.1999, B.P. Stark, 2♂, ♀ (BPSC). **Oklahoma:** LeFlore Co., tributary to Big Creek, NW Page, Hwy 59/270, 34.7144, -94.5547, 6.II.2003, B.C. Kondratieff, J.P. Schmidt, and R.E. Zuellig, 3♂, ♀ (CSUC); tributary to Big Creek, NW Page, Hwy 59/270, 34.7194, -94.5608, 6.II.2003, B.C. Kondratieff, J.P. Schmidt, and R.E. Zuellig, 4♂, 3♀ (CSUC); Big Creek, NW Page at Page Cemetery Rd., 34.7139, -94.5500, 6.II.2003, B.C. Kondratieff, J.P. Schmidt, and R.E. Zuellig, ♂ (CSUC); intermittent stream just E of Muse, Hwy 63, 34.6718, -94.7585, 15.III.2002, B.C. Kondratieff and R.E. Zuellig, 2♂ (CSUC).

Distribution. USA: AR (DeWalt et al. 2012), OK (new state record).

Remarks. This is the only *Zealeuctra* species that has a cleft bearing a secondary anterior extension. *Zealeuctra wachita* appears to be easily the least common of the three *Zealeuctra* species endemic to the Interior Plateau region. Poulton and Stewart (1991), in their study of the stoneflies of the Ozark and Ouachita Mountains, included only two Arkansas localities for this species. In contrast, the other two regional species, *Z. cherokee* and *Z. warreni*, plus *Z. claasseni* and *Z. narfi*, are markedly more common. The Oklahoma records noted above (Fig. 11) represent new state records.

Zealeuctra warreni Ricker & Ross

http://species-id.net/wiki/Zealeuctra_warreni
Figs 10, 13

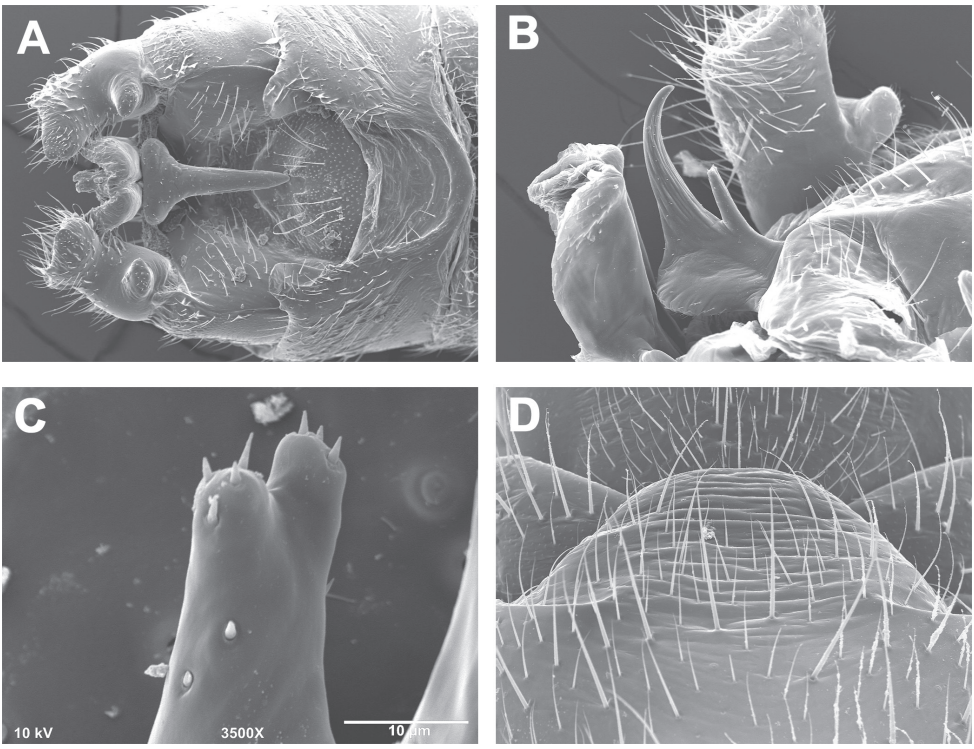
Zealeuctra warreni Ricker & Ross, 1969: 1120. Holotype ♂ (INHS), Sugar Creek, 5 mi E Hardy, Sharp Co., Arkansas

Description. Male - abdominal tergal cleft. Anterior portion broadly-rounded and U-shaped. Posterior portion V-shaped, with small crenulations evident along inner margins, terminating posteriorly with paired, subtriangular, medially-projected extensions (Fig. 10A).

Male - epiproct. Base broad and flanged laterally (Fig. 10A), with paired spines both originating from base, posterior spine ca. 2× length of anterior spine, moderately recurved anteriorly (Fig. 10B), anterior spine straight and bifurcated slightly at tip, with the paired terminal ends bearing four thick spines at tip (Fig. 10C).

Female - 7th sternum. Seventh sternum lacking medial lobe, with posteromedial portion overlapping as a broadly-triangular flap onto anteromedial margin of the eighth sternum (Fig. 10D).

Material examined. USA, **Arkansas:** Polk Co., Rock Creek, Hwy 71, 2 mi SW Mena, 34.5601, -94.2902, 26.X.1983, B.C. Poulton, 4♂ (CSUC); tributary to Casatot (sic Cossatot) River, 1.5 mi S Shady off AR 375, 34.4373,-94.1281, 11.XI.1990, S.R. Moulton & K.W. Stewart, 22♂, 19♀ (BYUC); Scott Co., Johnson Creek, Hwy



Figures 10. *Zealeuctra warreni*, scanning electron micrographs, USA, Arkansas, Polk Co., Rock Creek, 26 November 1983 (**A**), USA, Arkansas, Scott Co., Johnson Creek, 6 January 1999 (**B–D**). **A** male, cleft, dorsal view, 200× **B** male, epiproct, lateral view, 350× **C** male, tip of anterior accessory spine, anterior view, 3500× **D** female, posteromedial portion of seventh abdominal sternite, 350×.

49, 34.7131, -94.2101, 6.I.1999, B.P. Stark, 2♂, 5♀ (BPSC); Van Buren Co., Archy Creek, S of Woolum, W of Botkinburg, 35.6883, -92.6500, 7.II.2003, B.C. Kondratieff, R.E. Zuellig and J.P. Schmidt, 2♂, 2♀ (CSUC); Washington Co., Wildcat Creek, CR 870, 36.1223, -94.2460, 17.I.1999, B.P. Stark ♂ (BPSC); West Fork of the White River, 0.5 mi N Brentwood, at rest stop, 35.8663,-94.1188, 25.XI.1995, C.R. Nelson, ♂, 4♀ (BYUC); Cove Creek, 15 mi S Prairie Grove, 35.7758,-94.3748, 17.XI.1962, O. Hite and M. Hite, 4♂, 8♀ (BYUC). **Oklahoma:** LeFlore Co., Big Creek, Page, 34.7160, -94.5503, 5.I.2006, B.P. Stark, 2♂, ♀ (BPSC).

Distribution. USA: AR, MO, OK (DeWalt et al. 2012)

Remarks. *Zealeuctra warreni* males are easily distinguished from all *Zealeuctra* species by presence of the two prominent epiproct spines. The common name for this species, Early Needlefly (Stark et al. 2012), is apt since its November–February emergence period is earlier compared to each of the four other regional congeners (*Z. cherokee*, *Z. claasseni*, *Z. narfi*, and *Z. wachita*) in the Interior Highlands. Poulton and Stewart (1991) noted the emergence period for *Z. warreni* starts in November.

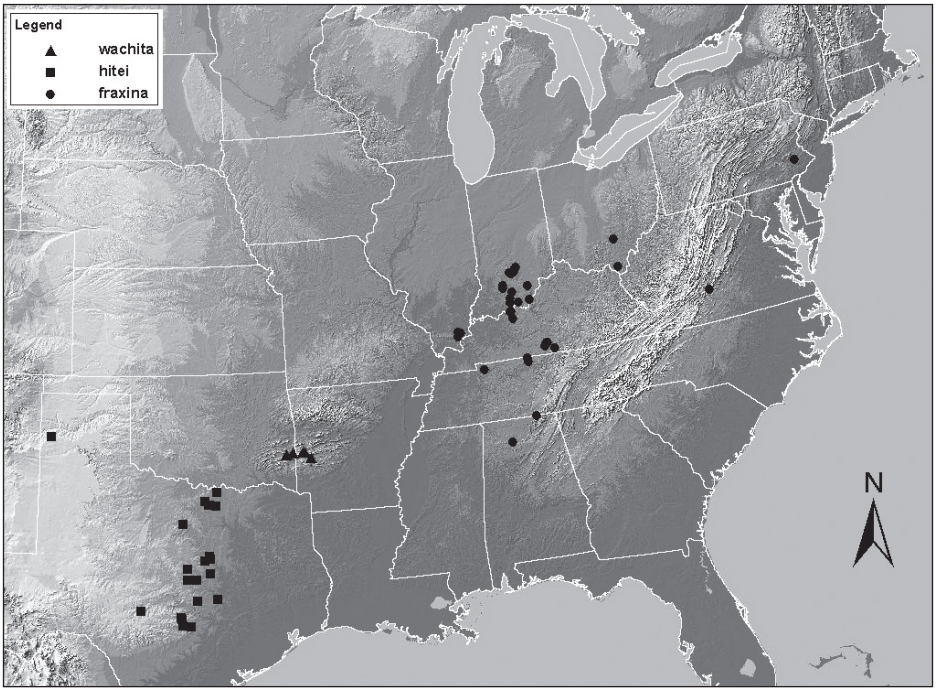


Figure 11. Distribution map for *Z. fraxina*, *Z. hitei*, and *Z. wachita*.

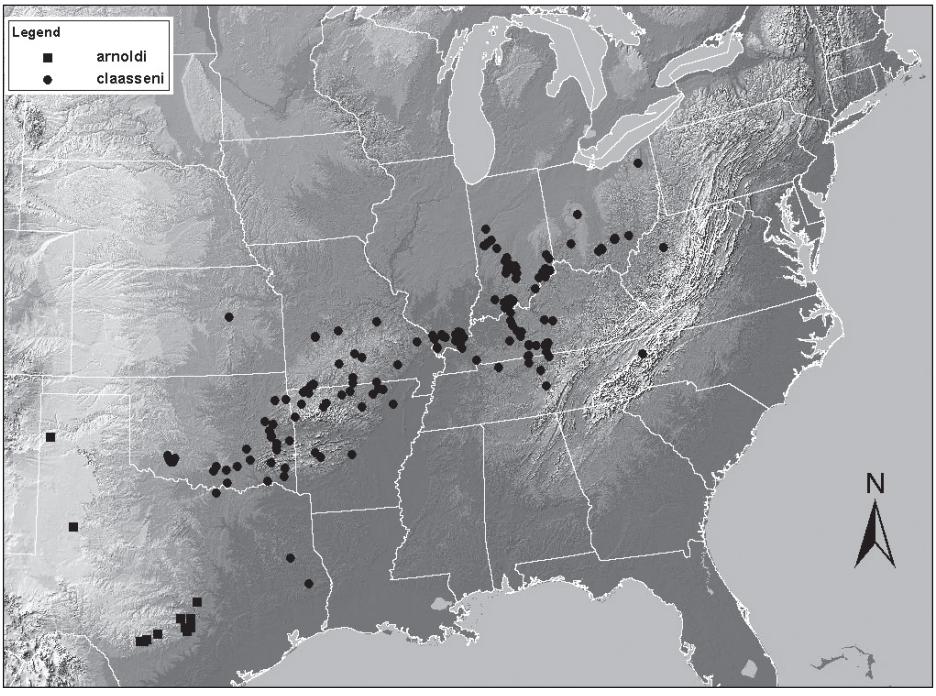


Figure 12. Distribution map for *Z. arnoldi* and *Z. claasseni*.

Figure 13. Distribution map for *Z. stewarti*, *Z. talladega*, *Z. ukayodi* sp. n., and *Z. warreni*.

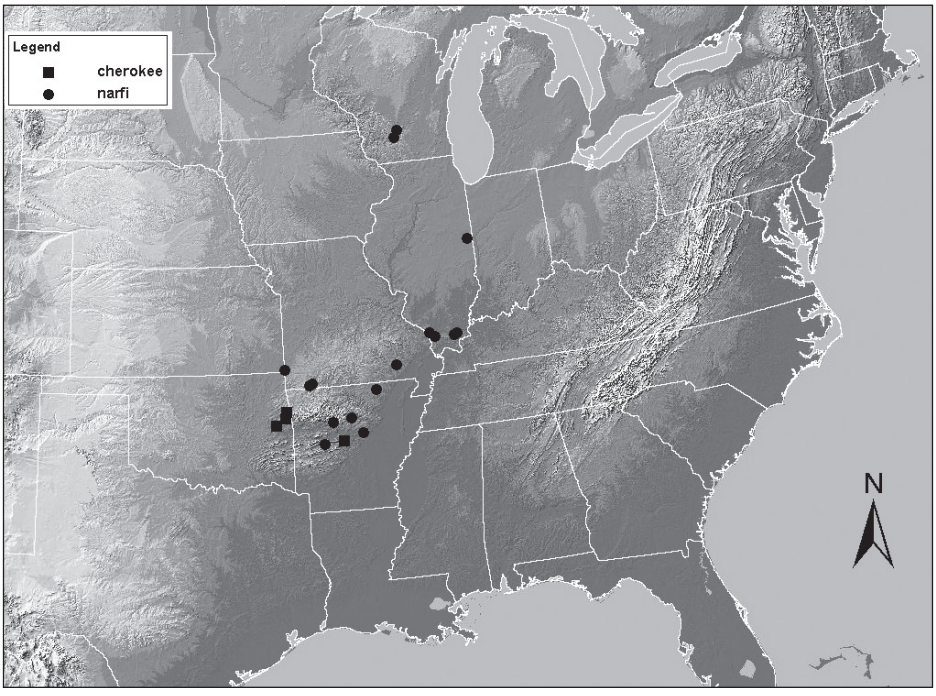


Figure 14. Distribution map for *Z. cherokee* and *Z. narfi*.

Acknowledgments

John Andersland (Western Kentucky University) assisted with SEM preparation and Massimo Pessino (Illinois Natural History Survey) kindly prepared the distribution maps. Richard W. Baumann (BYUC) is thanked for the loan of *Zealeuctra* material. Andrew Sheldon (Crawfordville, Florida) has been responsible for providing most of the *Z. talladega* specimens. Funding to support this research has been provided by Western Kentucky University Faculty Scholarship Grants and Summer Fellowships to SAG, a United States of America National Science Foundation DEB 09-18805 ARRA award to RED, and a United States Department of Interior grant X-1-R-1 to RED.

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RESEARCH ARTICLE

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Range extension of *Brathinus satoi* in China (Coleoptera, Staphylinidae)

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Abstract

Brathinus satoi Kishimoto & Shimada, 2003 is recorded from Longwangshan Nature Reserve, Zhejiang, China. Some diagnostic characters of the species are discussed based on more specimens, and some biological notes are made on the species.

Keywords

Coleoptera, Staphylinidae, *Brathinus satoi*, China

Introduction

Brathinus LeConte is a genus belonging to the Omaliinae. Bearing very long elytra covering most abdominal segments, adults of *Brathinus* are pretty bizarre, though their larvae (Thayer 1985) are rather typical Anthophagini. The adults could be misidentified as members of the Anthicidae or Staphylinidae: Scydmaeninae at first glance. In fact, *Brathinus* was originally described as a scydmaenid (LeConte 1852), later placed by LeConte (1861) in its own subfamily of Silphidae (sensu latissimo!), where it was when Lewis (1886) described the first Asian species, and treated as the family Brathinidae by Arnett (1963). Crowson (1955) first placed it in Omaliinae (or at any rate gave no earlier citation) and Hammond (1971) and Thayer (1985) provided more details and justification for that placement.

Presently, six species of the genus have been described: *B. californicus* Hubbard, 1894, *B. nitidus* LeConte, 1852 and *B. varicornis* LeConte, 1852 from North America, *B. oculatus* Lewis, 1886 and *B. shikokuensis* Watanabe & Sato, 1981 from Japan and *B. satoi* Kishimoto & Shimada, 2003 from China. The last species is the only species known from China, and was described from a single male specimen collected from Sichuan. More specimens of *B. satoi* were collected after many years of field work in Longwamgshan Nature Reserve of Zhejiang Province, which is more than 1000 kilometers from its type locality. Thus, some complementary comments on diagnostic characters and biological notes of the species can be provided.

Material and methods

For examination of the male genitalia, the last three abdominal segments were detached from the body after softening in hot water. The aedeagi, together with other dissected pieces, were mounted in Euparal (Chroma Gesellschaft Schmidt, Koengen, Germany) on plastic slides. Photos of sexual characters were taken with a Canon G7 camera attached to an Olympus SZX 16 stereoscope; habitus photos were taken with a Canon macro photo lens MP-E 65 mm attached to a Canon EOS40D camera. All the specimens treated in the paper were deposited in Department of Biology, Shanghai Normal University, P. R. China.

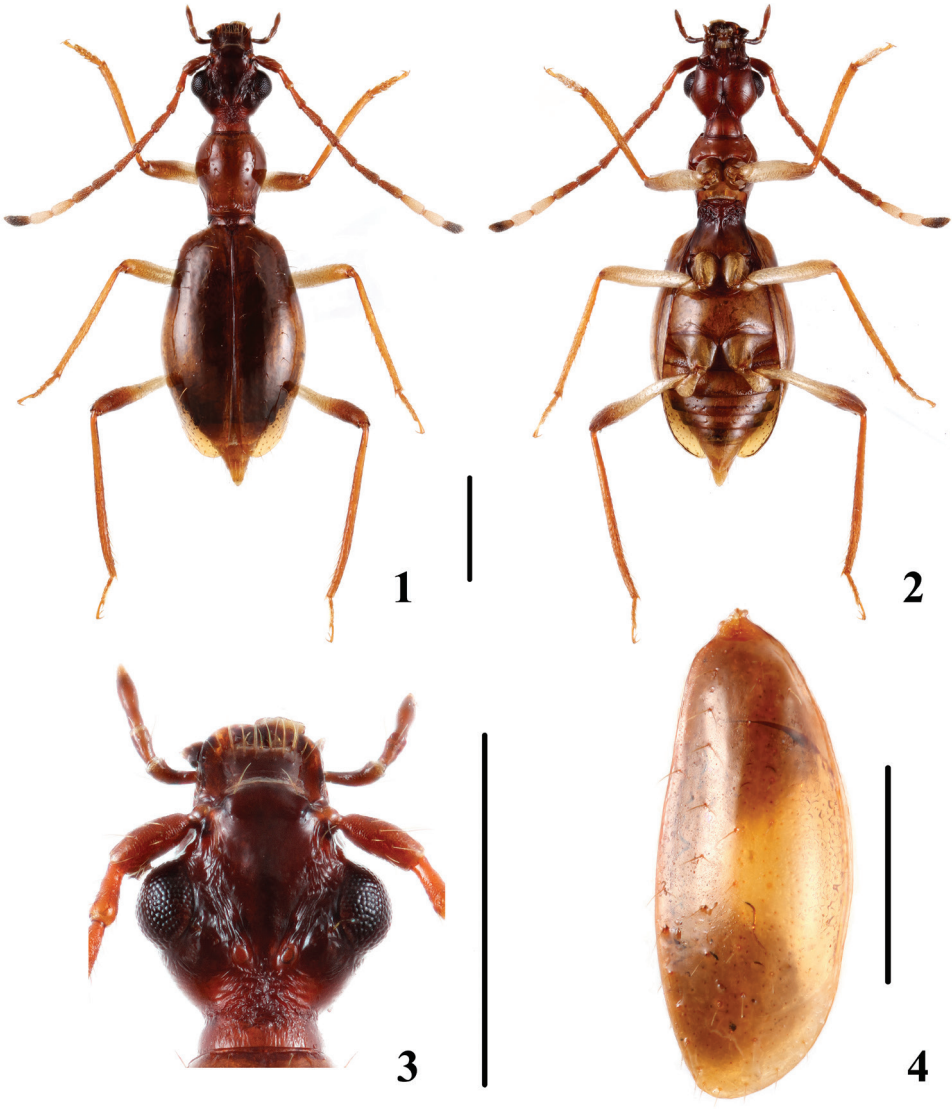
Taxonomy

***Brathinus satoi* Kishimoto & Shimada, 2003**
http://species-id.net/wiki/Brathinus_satoi
Figs 1–9

Material examined. China: Zhejiang: 1♀, Longwangshan, 1200m, 25.IV.2004, Jia-Yao Hu leg.; 1♂, Longwangshan, Qianmutian, 1300m, 24.V.2009, Feng & Yin leg.; 11♂♂ 5♀♀, same locality, 1250m–1450m, 30°23'N, 119°26'E, 14.V.2013, Yu, Li, Zheng, Chen, Pan, Hu & Tang leg.; 1♂, same locality, 1050–1200m, near 30°24'28"N, 119°26'25"E, 15.V.2013, Chen & Pan leg.

Distribution. China (Sichuan, Zhejiang).

Comments. This species can be easily recognized by rugose punctation along supraorbital furrows (Fig. 3) and several additional characters: antennae reddish brown with antennomeres 9 and 10 pale and antennomere 11 blackish; each elytron (Fig. 4) with a large yellowish mark extending from the elytral center to a broad yellowish band along the lateral margin, anterad and posterad from the midpoint; profemur and metafemur with approximately half of the apical portion darker, mesofemur with apical portion slightly darker (Figs 1, 2); median lobe of aedeagus with a sclerotized



Figures 1–4. *Brathinus satoi*. **1, 2** adult habitus, (1) dorsal, (2 ventral **3** head, dorsal **4** right elytron, dorsal. Scale lines = 1 mm.

apical portion which is delimited basally by a curved margin (Figs 5–7). In immature specimens, however, the elytral coloration is hardly discernible.

Biological notes. Most specimens were collected by sifting leaf litter along a stream in the forest, sometimes even along the bed of temporary brooks (Fig. 8). Two individuals were observed actively moving on the underside of a wet log lying close to a tiny stream (Fig. 9). In the past ten years, many collecting trips were made to Longwanshan

Figures 5–7. Aedeagus of *Brathinus satoi*. **5** ventral **6** lateral **7** dorsal. Scale line = 0.25 mm.

from the middle of April to the beginning of October, covering all altitudes of the area in each trip (300–1500m), and the collections show that the activity period of the adults is during late April through May at the higher altitudes of the area, above 1000m.

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Figures 8, 9. 8 Habitat in Longwangshan **9** *Brathinus satoi* moving on wet log.

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RESEARCH ARTICLE

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New North American Chrysauginae (Pyralidae) described by E.D. Cashatt

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Abstract

A Ph.D. dissertation completed by E.D. Cashatt in 1968 entitled "Revision of the Chrysauginae of North America" does not meet the criteria of publication so the new taxa described therein are not available per the International Code of Zoological Nomenclature. In order to validate the taxa proposed in that document we formally describe and illustrate the following: *Arta brevivalvalis* Cashatt, **sp. n.,** *Heliades lindae* Cashatt, **sp. n.,** *Paragalasa* Cashatt, **gen. n.**, *Paragalasa exospinalis* Cashatt, **sp. n.**, and *Penthesilea sacculalis baboquivariensis* Cashatt, **subsp. n.** We summarize other taxonomic actions proposed in the dissertation and those proposed by subsequent authors. We provide the current nomenclatural status with the literature citation of the paper in which the current status was proposed. A lectotype is designated for *Clydonopteran tecomae*. Adult holotypes and associated labels, and genitalia of paratypes are newly illustrated.

Keywords

Chrysauginae, Pyralidae, North America, *Campsis radicans*

Introduction

Cashatt's (1968) Ph.D. dissertation entitled "Revision of the Chrysauginae of North America" included numerous nomenclatural acts that are unavailable according to the most recent International Code of Zoological Nomenclature (ICZN 1999). Cashatt distributed only two copies of his dissertation (Cashatt 1968) on North American Chrysauginae: the mandatory one at Catholic University of America, and one at the library at The Natural History Museum, London, thus the entire dissertation does not constitute a published work (ICZN 1999, p. 6, Article 8). In 1969, *Dissertation Abstracts International* published and widely distributed the abstract of this dissertation and offered copies of the dissertation for sale. Whether the dissertation (Cashatt 1968) minimally meets criteria for what constitutes a published work (i.e. ICZN, Article 8, p. 6) is ambiguous (Haman and Huddleston 1980). As an example, Fletcher and Nye (1984) considered the names *Basacallis* and *Paragalasa* available stating: "Cashatt's revision was originally a dissertation submitted to the Catholic University of America for the degree of Doctor of Philosophy. It was published on paper by University Microfilms International (UMI) and has been available since June 1969 when it was advertised for sale in *Diss. Abst. Int.* (B) 29(12): 4696." Fletcher and Nye (1984) include these genera only because a copy was available to them at The Natural History Museum in London. The work was not accessible, however, to other institutions or scientists in the world short of visiting London or Catholic University. In contrast, Cashatt believed his dissertation to be unpublished, and he wrote a formal description of *Basacallis* in 1984. In our opinion the ICZN Recommendation (ICZN 199, p. 9, 8A) that dissemination should be in scientific journals and series, precludes the assumption of two copies constituting wide availability. In addition, the Code recommends that new names be sent to *Zoological Record*, but in this case they were not. So while the abstract published by UMI was widely available, we propose that the nomenclatural acts in the rest of the dissertation are not available.

In this work we make available by publication the taxa described in the dissertation by Cashatt (1968). We replicate the text from the dissertation with minimal editing (only as needed) from the dissertation for *Arta brevivalvalis* Cashatt, sp. n., *Heliades lindae* Cashatt, sp. n., *Paragalasa* Cashatt, gen. n., *Paragalasa exospinalis* Cashatt, sp. n., and *Penthesilea sacculalis baboquivariensis* Cashatt, subsp. n. We update the terminology of the genitalia, but not that of the wing venation. We attribute authorship of all taxa to E. D. Cashatt. We include redescriptions of the monotypic *Penthesilea* Ragonot, 1891 and *Penthesilea sacculalis sacculalis* Ragonot, 1891 because the new subspecies description would have been difficult to comprehend otherwise. We provide illustrations of the adults and genitalia (i.e., not the illustrations from the dissertation) from the type specimens located in the National Museum of Natural History, Washington, DC (USNM). We also summarize other taxonomic actions (Table 1) by Cashatt (1969) and the current status of taxa in two major taxonomic lists, the Moths of America north of Mexico (Munroe 1983), and the Atlas of Neotropical Lepidoptera (Solis et al. 1995). Cashatt (1968) used the following acronyms for collections where

material is deposited: AMNH (American Museum of Natural History, New York, USA), CNC (Canadian National Collection, Ottawa, Canada), CU (=CUIC, Cornell University Insect Collection, Ithaca, New York, USA), USNM (=NMNH, National Museum of Natural History, Washington, DC, USA).

Taxonomic actions (see Table 1)

In his abstract, Cashatt (1969) stated, "*Clydonopteron* Riley is reinstated as a genus separate from *Salobrena* Walker"; it had been synonymized by Hampson (1897). The revised status of *Salobrena* is valid and attributable to Cashatt (1969). In the dissertation, Cashatt (1968) also synonymized *C. tecomae* Riley, 1880 as a junior synonym of *Pyralis sacculana* Bosc, [1800]. This synonymy was independently discovered and published by Miller and Becker (1989) as a new synonymy (see Landis et al. 1992); so the correct attribution of the status of *C. tecomae* as a junior synonym of *P. sacculana* is Miller and Becker (1989). Miller and Becker (1989) also newly combined *P. sacculana* in *Clydonopteron*; so the correct attribution for the new combination *Clydonopteron sacculana* is Miller and Becker (1989). In the dissertation Cashatt (1968) stated he was unable to locate the type specimen of *P. sacculana*, but based on illustrations he was "convinced it is conspecific with *tecomae*." He located two female types of *C. tecomae* without locality data, but labeled "1878, USNM Type No. 366" in the USNM. He designated one of these specimens as the lectotype and the other as the paralectotype. The lectotype and paralectotype are newly designated here with attribution to Cashatt, and labeled as such in the USNM. Cashatt noted that Riley (1880) also provided a description of the life history; eggs are laid in seedpods of trumpet vine (*Campsis radicans* (L.) Seem. ex Bureau, Bignoniaceae) where larvae and pupae develop. Landis et al. (1992) published more on the biology of this species and described the egg stage. In Landis et al. (1992) EDC mistakenly used the year 1969 for the date of his dissertation in the References Cited.

Cashatt (1984) described the new genus *Basacallis* Cashatt and designated *Parachma tarachodes* Dyar, 1914, as the type species, and that is the correct attribution for availability and validity. Solis et al. (1995) correctly attributed this genus to Cashatt, but used the incorrect date of 1969, instead of 1984.

In the dissertation Cashatt (1968) synonymized the following genera and transferred and/or synonymized type species. *Artopsis* Dyar, 1908 was synonymized with *Parachma* Walker, [1866] in the checklist (Cashatt 1968), and it did not appear in the abstract (Cashatt 1969). Attribution for this synonymy should be Barnes and McDunnough (1917) where it first appeared, although it was not stated explicitly. Cashatt (1968) synonymized the type species, *Artopsis borregalis* Dyar, 1908 with *Parachma ochracealis* Walker, [1866], and published this new synonymy in Cashatt (1984), but Solis et al. (1995) revised the status of *borregalis*, considering it a valid species. Herein we synonymize *A. borregalis* with *P. ochracealis*, revised status**,** and attribute this action to Cashatt. In addition, Cashatt (1968) listed 1909 as the date of publication for

Table 1. Nomenclatural acts and attributions relating to taxa in Cashatt (1968). See text for more information.

Taxon name	Action	Attribution
Salobrena Walker, 1863	Revised status as genus	Cashatt (1969)
Clydonopteron tecomae Riley, 1880	Synonym of *Pyralis sacculana*	Miller and Becker (1989)
Pyralis sacculana Bosc, [1800]	Combination in *Clydonopteron* Riley	Miller and Becker (1989)
Basacallis Cashatt, 1984	Genus description	Cashatt (1984)
Artopsis Dyar, 1908	Synonym of *Parachma* Walker	Barnes and McDunnough (1917)
Artopsis borregalis Dyar, 1908	New revised status of *Parachma ochracealis*	Present paper
Polloccia Dyar, 1910	Synonym of *Acallis* Ragonot	Cashatt (1969)
alticolalis Dyar, 1910	Combination in *Acallis* Ragonot	Solis et al. (1995)
Balidarcha Dyar, 1914	Synonym of *Anemosella* Dyar	Cashatt (1969)
cuis Dyar, 1914	Synonym of *viridalis* B.&McD.	Munroe (1983)
cuis Dyar, 1914	Combination in *Anemosella* Dyar	Munroe (1983)
Xantippides Dyar, 1908	Synonym of *Arta* Grote	Cashatt (1969)
descansalis Dyar, 1908	Synonym of *Arta epicoenalis* Ragonot	Munroe (1983)
descansalis	Combination in *Arta* Grote	Munroe (1983)
centralis Dyar, 1910	New synonym of *Acallis gripalis* Hulst	Present paper
polingalis B.& B., 1926	New synonym of *Anemosella basalis* Dyar	Present paper
beatifica Dyar, 1921	New synonym of *Arta epicoenalis* Ragonot	Present paper
beatifica Dyar, 1921	New combination in *Arta* Grote	Present paper
uranides Dyar, 1921	New synonym of *Heliades mulleolella* Hulst	Present paper
uranides Dyar, 1921	New combination in *Heliades* Ragonot	Present paper
Heliades huachucalis Haimbach, 1915	New revised status as species	Present paper
Negalasa rubralis B. & McD., 1913	Revised status as species	Solis et al. (1995)
Arta brevivalvalis	New species	Present paper
Heliades lindae	New species	Present paper
Paragalasa	New genus	Present paper
Paragalasa exospinalis	New species	Present paper
Penthesilea sacculalis sacculalis	New revised status as subspecies	Present paper
Penthesilea sacculalis baboquivariensis	New subspecies	Present paper

Artopsis and *A. borregalis* which should have been 1908, but the confusion of the year is due to the publication of volume 10 of the Proceedings of the Entomological Society of Washington in two different years; issues 1 and 2 (pp. 1–118) in 1908 and issues 3 and 4 (pp. 119–221) in 1909.

Cashatt (1968) synonymized *Polloccia* [misspelled in the dissertation as *Pollocia*] Dyar, 1910 with *Acallis* Ragonot, 1891 and transferred the type species, *Polloccia alticolalis* Dyar, 1910 to *Acallis.* The abstract (Cashatt 1969) mentions this generic synonymy so the correct attribution for the status of *Polloccia* as a junior synonym of

Acallis is Cashatt (1969). The abstract (Cashatt 1969) did not transfer the type species, but Solis et al. (1995) newly combined *P. alticolalis* in *Acallis,* so Solis et al. (1995) is the correct attribution.

Cashatt (1968) synonymized *Balidarcha* Dyar, 1914 with *Anemosella* Dyar, 1914 and the generic synonymy does appear in the abstract (Cashatt 1969), so the correct attribution of the status of *Balidarcha* as a junior synonym of *Anemosella* is Cashatt (1969). Cashatt (1968) synonymized *Balidarcha cuis*, Dyar, 1914 with *Anemosella viridalis* Barnes & McDunnough, 1912. The abstract (Cashatt 1969) did not transfer or synonymize the type species, but Munroe (1983) treated *B. cuis* as a new synonym, and as a new combination although not stated, so the correct attribution for the status of *B. cuis* as a junior synonym of *A. viridalis* and a new combination in *Anemosella* is Munroe (1983). *Balidarcha cuis* was also treated as a synonym by Solis et al. (1995).

Cashatt (1968) synonymized *Xantippides* Dyar, 1908 with *Arta* Grote, 1875 and transferred the type species, *Xantippides descansalis* Dyar, 1908 as a synonym of *Arta epicoenalis* Ragonot, 1891. The generic synonymy appears in the abstract (Cashatt 1969), so the correct attribution of the status of *Xantippides* as a junior synonym of *Arta* is Cashatt (1969). The transfer of the type species does not appear in the abstract (Cashatt 1969). Munroe (1983) published the synonymy of *X. descansalis* as a new combination and new synonymy, so the correct attribution for the status of *X. descansalis* as a new combination and junior synonym of *A. epicoenalis* is Munroe (1983).

Cashatt (1968) synonymized the following species in his dissertation, but they do not appear in the abstract (Cashatt 1969) so we newly synonymize these species below. Cashatt (1968) synonymized *Acallis centralis* Dyar, 1910 with *Acallis gripalis* Hulst, 1886. Munroe (1983) and Solis et al. (1995) treated *A. centralis* as a valid species of *Acallis*. Herein we synonymize *A. centralis* with *A. gripalis*, new synonymy, with attribution to Cashatt.

Cashatt (1968) synonymized *Anemosella polingalis* [misspelled in the dissertation as *pollingalis*], Barnes and Benjamin 1926 with *Anemosella basalis* Dyar, 1914. It was treated as a valid species by Munroe (1983) and Solis et al. (1995). Herein we synonymize *A. polingalis* with *A. basalis*, new synonymy, with attribution to Cashatt.

Cashatt (1968) synonymized and combined *Xantippe beatifica* Dyar, 1921 with *Arta epicoenalis* Ragonot, 1891. It was treated as a valid species of *Xantippe* by Munroe (1983) and Solis et al. (1995). Herein we synonymize *X. beatifica* with *A. epicoenalis*, new combination, new synonymy, with attribution to Cashatt.

Cashatt (1968) synonymized and combined *Xantippe uranides* Dyar, 1921 with *Heliades mulleolella* (Hulst, 1887). It was treated as a valid species in *Xantippe* in Munroe (1983) and Solis et al. (1995). Herein we synonymize *X. uranides* with *H. mulleolella*, new combination, new synonymy, with attribution to Cashatt.

Haimbach (1915) described *Pyrausta huachucalis*, but McDunnough (1939) revised its status as a junior synonym of *Heliades mulleolella* Hulst, 1887. Munroe (1983) and Solis et al. (1995) also treated *H. huachucalis* as a junior synonym of *H. mulleolella.* Cashatt (1968) elevated *H. huachucalis* to species stating: "…this western

species is distinct from the eastern one." Herein we elevate *H. huachucalis* to species status, revised status, with attribution to Cashatt.

Negalasa rubralis Barnes & McDunnough, 1913 was treated as a subspecies of *N. fumalis* by Munroe (1983) but was not clearly stated to be a revised status; it is historically interesting to note that Cashatt (1968) did the same thing. *Negalasa rubralis* was elevated back to species by Solis et al. (1995), but again it was not clearly stated to be a revised status. Due to the ambiguity of its status, we are leaving this status as determined by Solis et al. (1995).

Taxon descriptions

***Arta brevivalvalis* Cashatt, sp. n.**
http://zoobank.org/BC60CF21-AF03-4025-B272-251827BA2B87
http://species-id.net/wiki/Arta_brevivalvalis
Figs 1, 5–7

Description. Head. Labial palpus reddish-brown laterad, inner surface ochreous; frons and vertex light reddish-brown to purplish; occiput tan to ochreous.

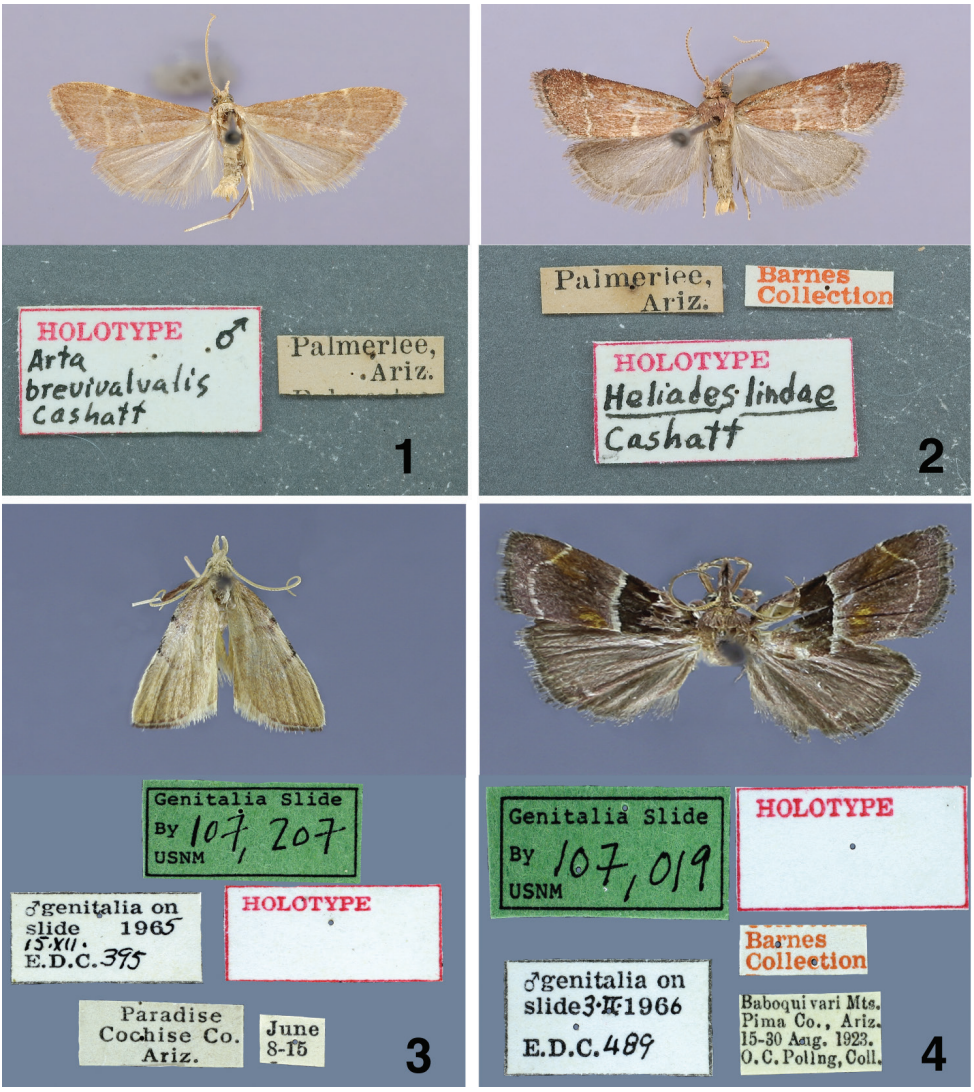
Thorax. Upper surface reddish-brown to tan, under surface darker. Forewing reddish- to purplish-brown with ochreous antemedial and postmedial lines; antemedial line irregular and extending obliquely from two-thirds costa to nearly one-half hind margin; postmedial line irregular and directed slightly inward near costa, extending from three-fifths costa to near anal angle; distance between the two lines greater at costa than at hind margin; fringe ochreous; under surface brown, purplish-red near costa and outer margin. Hind wing grayish-brown with ochreous fringe; underside purplish-red near costa and outer margin, a short postmedial line from costa fading inward. Legs purplish-brown with mid femur, midtibia, and inner surface of hind leg ochreous.

Abdomen. Ochreous dorsad, reddish-brown ventrad, terminal fringe ochreous.

Male genitalia. Uncus broad and shovel-shaped; tegumen narrow, pedunculus unmodified; vinculum broad, saccus not narrowly produced anteriad as in *statalis*, but rounded; juxta acutely hooked dorsad near base with apex directed slightly dorsad; valva as in *statalis* except shorter with a broader base, apex unidentate; phallus long and slender with apex flattened without a coecum or cornutus.

Female genitalia. Ovipositor moderately enlongate, papillae anales small and unilobate; posterior apophysis extremely short; anterior apophysis short as in *statalis;* ostium bursae wide; lamella antevaginalis broad and V-shaped, opening near anterior margin of eighth sternite; bursa copulatrix simple with inception of ductus seminalis below antrum; without a signum.

Type data. The type specimens are located as noted below. The male holotype is from Palmerlee, Arizona (no other data given) and is labeled as the holotype. Fifty-three male and twenty-two female paratypes from UNITED STATES: ARIZONA are labeled as follows: two females, Catalina Mts., no date given, Oslar Coll. (USNM);



Figures 1–4. Male holotypes of adults and labels. **1** *Arta brevivalvalis* **2** *Heliades lindae* **3** *Paragalasa exospinalis* **4** *Penthesilea sacculalis baboquivariensis*.

two males and two females, Catalina Mts., June 10, 1903, Oslar, Coll. (USNM); one female, Huachuca Mts., (USNM); one male, Madera Canyon, Santa Rita Mts., Aug. 18, 1953, Robert J. Ford (CNC); one male and one female, Madera Canyon, Santa Rita Mts., Aug. 19, 1953. Robert J. Ford (CNC); one male, Madera Canyon, Santa Rita Mts., Aug. 9, 1953 (CNC); one male, Palmerlee, Sept. 8–15 (USNM); twenty-five males and nine females, Palmerlee, no date given (USNM); seven males and four females, Ramsey Canyon, Huachuca Mts., Sept. 1-2, 1927, J. C. Bradley Coll. (CU); ten males and two females, White Mts., elevation 7200 ft., Aug. 1–15, 1925, Poling Coll. (USNM); one male and one female, White Mts., elevation 7200–11500 ft., Aug.

10–30, 1925, O. C. Poling (USNM); three males, White Mts., Apache Co., near McNary P. O., Sept. 15–30, 1925, O. C. Poling.

Life history. Unknown.

Remarks. It is difficult to separate *brevivalvalis* from *statalis* and *epicoenalis* on the basis of maculation. The ochreous fringe is sometimes a useful diagnostic character but is not reliable. The distance between the antemedial and postmedial lines is variable.

An examination of the genitalia is necessary for accurate identification. The flattened and spade-shaped uncus of *brevivalvalis* easily separates this species from *statalis* and *olivalis* that have a narrow and more cylindrical shape. The valva of *olivalis* is long and slim. The uncus of *epicoenalis* is flattened, but not constricted at the base as in this species. The ostium bursae of *brevivalvalis* is broad compared to that of *statalis*, and the anterior apophyses are extremely short. The anterior apophyses of *olivalis* and *epicoenalis* are absent.

***Heliades lindae* Cashatt, sp. n.**
http://zoobank.org/F91B3D1C-706B-4341-80C4-10AA5117497D
http://species-id.net/wiki/Heliades_lindae
Figs 2, 8–10

Description. Alar expanse. 15 to 17 mm.

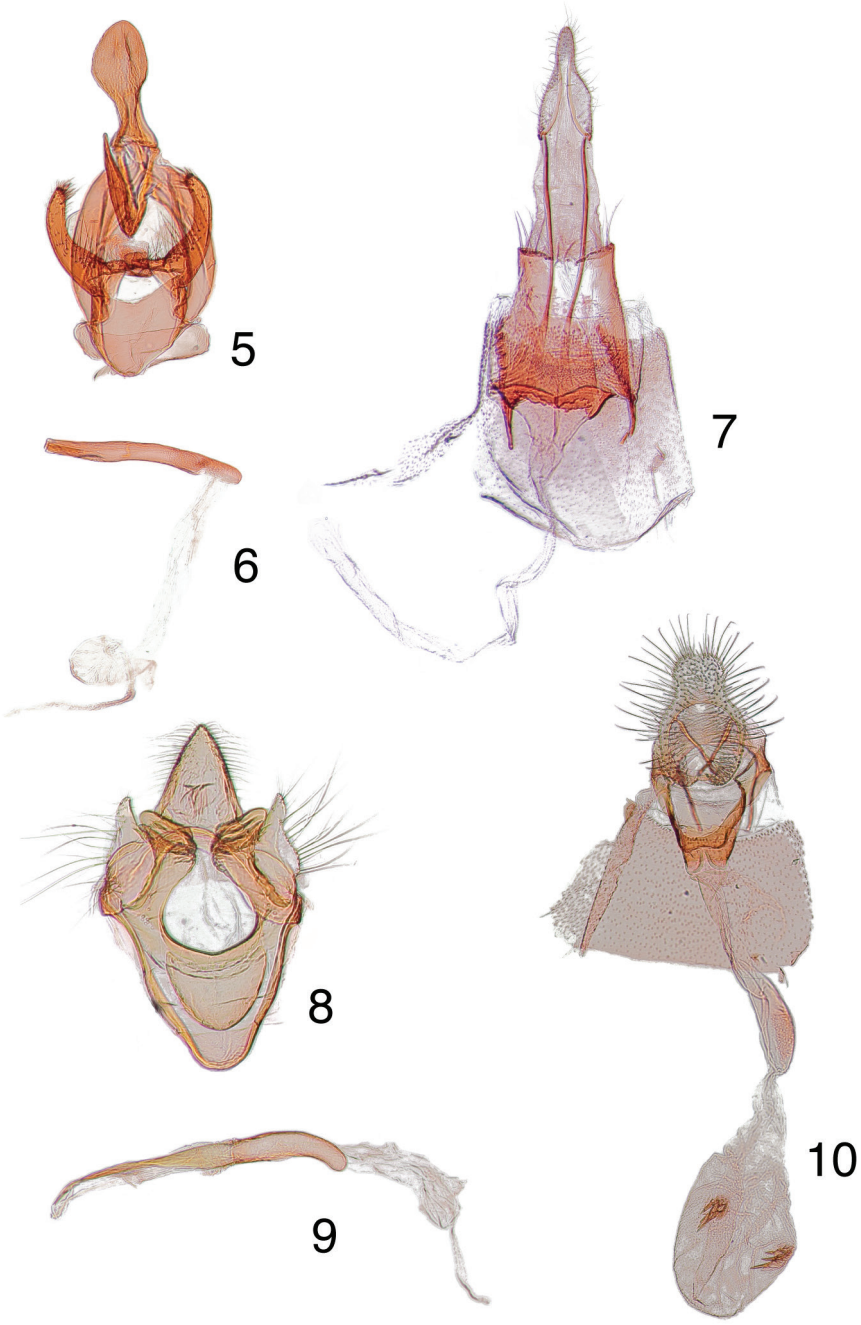
Head. Labial palpus dark reddish-brown with fuscous on under surface; frons, vertex, occiput, and antenna brownish-red.

Thorax. Upper surface brownish-red; under surface fuscous. Forewing brownish-red with white dentate antemedial and postmedial lines; antemedial line extending from about two-fifths costa to nearly two-fifths inner margin, postmedial line extending from three-fourths costa to just proximad of anal angle; terminal line fuscous; fringe gray with a dark medial line; under surface grayish-brown with apex brownish-red. Hind wing light grayish-brown; fringe gray with a dark medial line, under surface gray with apex reddish-brown. Legs fuscous with midtibia and tarsus white.

Abdomen. Upper surface concolorous with hind wings; terminal fringe ochreous.

Male genitalia. Uncus long and aculeate, setose dorsad; tegumen narrow dorsad; vinculum broad with a well-developed saccus, but more broadly rounded; gnathos reduced to a slender arm articulating at base of uncus; valva with sacculus small and papilliform, setose; valva heavily sclerotized and plate-shaped with apex truncate, ankylosed with flat truncate tips of arms produced by juxta; juxta shield-shaped and ankylosed with inner margin of vinculum; phallus long and slender, coecum well-developed.

Female genitalia. Ovipositor extremely short; apex of papillae anales bilobate and broad; eighth segment extremely short; anterior apophysis about one-half length of posterior apophysis; opening of ostium bursae at anterior of eighth sternite, small and sclerotized; anterior margin of sinus vaginalis bilobate and more broadly joined to the anterior margin of the eighth sternite; inception of ductus seminalis below antrum;



Figures 5–10. Male, female genitalia. **5** *A. brevivalvalis* paratype male, USA, Arizona, Palmerlee, [no collection date on label], EDC 981, USNM 104473 **6** phallus, data same as previous **7** paratype female, USA, Arizona, Palmerlee, [no collection date on label], EDC 982, USNM 104474 **8** *H. lindae* paratype male, USA, Arizona, Palmerlee, [no collection date on label], EDC 80, USNM 105993 **9** phallus, data same as previous **10** paratype female, USA, Arizona, Palmerlee, [no collection date on label], EDC 84, USNM 104482.

ductus bursae weakly sclerotized and constricted near junction of corpus bursae; signum a pair of spines.

Type data. All the type specimens are in the USNM. The male holotype is from Palmerlee, Arizona (no other data given) and is labeled as the holotype. Twenty-three male and nineteen female paratypes from UNITED STATES: ARIZONA are labeled as follows: one female, Baboquivari Mts., Pima Co., 1-15 Sept. 1923, O. C. Poling; one male, Chiricahua Mts., July 4, H. G. Hubbard; one male, Fort Grant, July 20, H. G. Hubbard; one female, Hereford, no date, C. R. Biedermann; one male, Huachuca Mts., no date; one female, Huachuca Mts., Aug. 8-15; one male, Madera Canyon, Santa Rita Mts., Aug. 19, 1953, Robert J. Ford; one male, Nogales, July 15, 1903, Oslar; one female, Oracle, July 28, 1924, E. P. Van Duzee; nine males, four females, Palmerlee, no date given; one female, Palmerlee, Cochise Co., Aug. 1–7; one male, one female, Paradise, Cochise Co., no date; four males, five females, Paradise, Cochise Co., July; two females, Paradise, Cochise Co., Aug.; one female, Paradise, Cochise Co., Aug. 1–7; one male, S.W.R.R., 5 mi. W. Portal, Cochise Co., 5400 ft., July 9, 1956, Cazier and Ordway; one female, Santa Catalina Mts., no date given; one male, White Mts., El. 7000 ft., July 15–22, 1925, O. C. Poling.

Life history. Unknown.

Remarks. It gives me pleasure to name this species in honor of my wife, Linda. The coloration of *lindae* is similar to *huachucalis* except the former is lighter and more reddish. The antemedial and postmedial lines of *huachucalis* are white, but unlike *lindae* the lines are margined with fuscous.

Paragalasa Cashatt, gen. n.

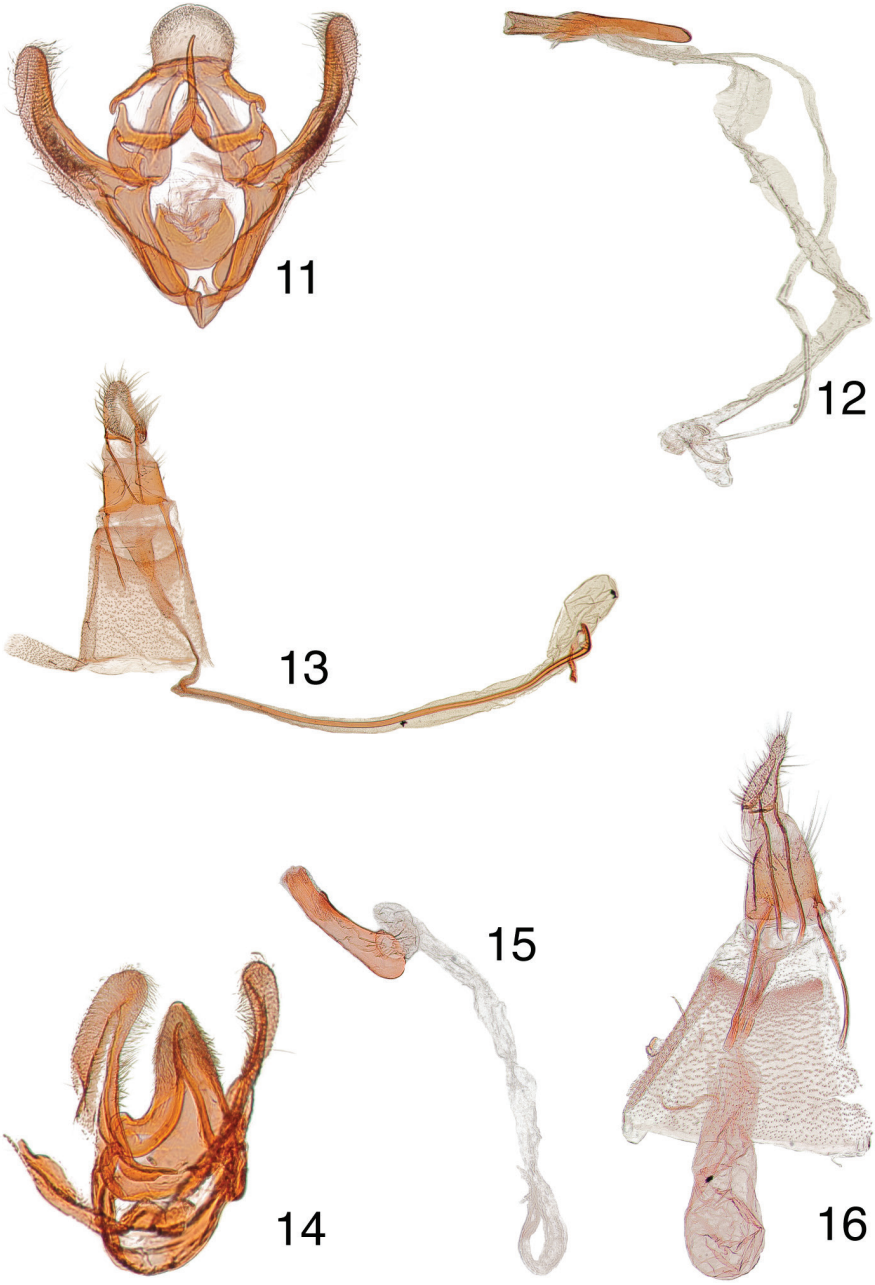
http://zoobank.org/E96A1722-5429-4294-9CCC-8A2727C56859
http://species-id.net/wiki/Paragalasa
Figs 3, 11–13

Paragalasa Cashatt, 1968, *nomen nudum*, Solis et al. 1995

Type species. *Paragalasa exospinalis*, Cashatt, new species.

Description. Head. Labial palpus porrect, length approximately equal to head width; maxillary palpus vestigial, two segmented, pilifers moderately developed; proboscis well developed; frons rounded with a tuft produced obliquely; vertex and occiput roughly scaled; ocellus immediately posteriad to base of antenna; chaetosema a row of fine setae along ocular sutura posteriad to ocellus.

Thorax. Forewing long and narrow, costa slightly incurved near middle, apex sublanceolate, outer margin rounded; sexually dimorphic: male with a small glandular vesicle at base of costa, discal cell shorter than in female, R_1 not reaching costa, posterior angle obtuse; female without a glandular vesicle, R_1 intercepting the costa, posterior angle of discal cell acute; both sexes with Sc long, R_1 arising from just before end of discal cell; R_2 stalked short with R_3, R_4, and R_5, stem arising from anterior angle of discal cell; R_3 stalked with R_4 and R_5; R_4 and R_5 coincident; M_1 separate, arising from anterior angle of discal cell; male with M_2 separate, M_3 end Cu_1 stalked short; Cu_2 separate, arising



Figures 11–16. Male, female genitalia. **11** *Paragalasa exospinalis* holotype male, USA, Arizona, Cochise Co., Paradise, June 8-15 [no year given], EDC 395, USNM 107207 **12** phallus, data same as previous **13** paratype female, USA, Arizona, Redington, [no collection date on label], EDC 398, USNM 107089 **14** *Penthesilea sacculalis baboquivariensis* holotype male, USA, Arizona, Pima Co., Baboquivari Mts., 15–30 Aug 1923, O.C. Poling, Coll., Barnes Collection, EDC 489, USNM 107019 **15** phallus, data same as previous **16** allotype female, USA, Arizona, Pima Co., Baboquivari Mts., [days crossed out] Aug 1924, O.C. Poling, Coll., Barnes Collection, EDC 138, USNM 100018.

from posterior angle of discal cell; female M_2 and M_3 stalked short, Cu_1 and Cu_2 widely separated; 2A and 3A separate at base, anastomosed briefly a short distance from base; retinaculum normally developed. Hind wing frenulum normal; Sc and Rs anastomosed beyond end of discal cell; M_1 separate from anterior angle of discal cell; M_2 and M_3 short stalked from posterior angle of discal cell; posterior angle of discal cell extremely long and slender; Cu_1 and Cu_2 widely separated. Legs long, midtibia with two scale tufts.

Abdomen. Long and slender, without scale tufts.

Mala genitalia. Uncus moderately broad with apex rounded, slender arms from base modified to articulate with gnathos; tegumen narrow dorsad; pedunculus strongly modified for articulation with gnathal arms; vinculum moderately broad with saccus slightly produced; gnathos slender and aculeate, apex hooked dorsad; valva with sacculus distinct from valva, ventral margin of sacculus rounded; transtilla weak and incomplete; juxta with dorsal margin V-shaped; phallus small, coecum long, apex with microspines, cornutus with spines short and spur-shaped.

Female genitalia. Ovipositor moderately long; papillae anales apex unilobate; anterior apophysis slightly longer than posterior apophysis; lamella postvaginalis triangulate; ostium bursae membranous, antrum lightly sclerotized, inception of ductus seminalis just below antrum; ductus bursae extremely long; corpus bursae small and without a signum.

Remarks. The venation and genitalia indicate a close relationship between this genus and *Negalasa*. The male *Paragalasa* has a small glandular vesicle at the base of the costa on the forewing, but is without a costal spur. The costa is straight. *Negalasa* and *Galasa* have a larger glandular vesicle, an incurved costal margin and a costal spur at the end of Sc. The uncus of *Negalasa* is more narrow and pointed, the tip of the valva is directed acutely mediad, and the phallus has a broadly rounded coecum and cornutus with long spines. The male genitalia of *Paragalasa* is similar to *Galasa* except the dorsal margin is V-shaped, there is no process on the sacculus, and the phallus is smaller with a long cylindrical coecum and a small cornutus. The female *Paragalasa* has the inception of the ductus seminalis just below the antrum. The ductus bursae is extremely long with a small corpus bursae. *Negalasa* has the inception of the ductus seminalis more sclerotized, nearly two-thirds length from ostium bursae, and a large corpus bursae. The female venation of *Paragalasa* and *Negalasa* is identical. The male forewing of *Negalasa* shows more specialized structures.

***Paragalasa exospinalis* Cashatt, sp. n.**
http://zoobank.org/8B654928-5F29-4939-A494-E15FB480B90A
http://species-id.net/wiki/Paragalasa_exospinalis
Figs 3, 11–13

Paragalasa exospinalis Cashatt, 1968, *nomen nudum*, Solis et al. 1995

Description. Alar expanse. 19 to 22 mm.

Head. Labial palpus ochreous, darker laterad; frons, vertex, and occiput ochreous to tan; antenna ochreous.

Thorax. Upper surface pale reddish-brown, lower surface reddish-brown. Forewing pale reddish-ochreous; costa irrorated with fuscous, especially at base and at origin of antemedial and postmedial lines; antemedial line light reddish-brown, indistinct, extending from about one-third length of costa to about one-third length of inner margin; postmedial light reddish-brown and extending from about two-thirds length of costa sharply excurved to about two-thirds length of inner margin. Hind wing light pinkish to brownish-white with terminal line darker; fringe ochreous to brownish-ochreous. Legs ochreous, sprinkled with dark brown laterad, midtibia scale tufts fuscous.

Abdomen. Upper surface greyish-ochreous, fuscous laterad, lower surface ochreous.

Genitalia. As described for the genus.

Type data. All the type specimens in the USNM. The male holotype is from Paradise, Cochise Co., Arizona, June 8–15 and is labeled as the holotype. Twenty-six male and thirteen female paratypes from UNITED STATES: ARIZONA are labeled as follows: UNITED STATES: ARIZONA: eighteen males and two females, Baboquivari Mts., Pima Co., Ariz., elevation approximately 5000 ft., 15–30 June, 1923, O. C. Poling Coll.; four males, Brown's Canyon, Baboquivari Mts., Pima Co., Ariz., elevation approximately 5000 ft., 1–15 June 1923, O. C. Poling Coll.; one female, Brown's Canyon, Baboquivari Mts., Pima Co., Ariz., elevation approximately 5000 ft., 15–30 May 1923, O. C. Poling Coll.; two females, Huachuca Mts., Ariz., no date given; three males and three females, Palmerlee, Arizona, no date given; one male, Paradise, Cochise Co., Ariz., June 8–15; one male, Paradise. Cochise Co., Ariz., July; one male and two females, Redington, Ariz., no date given; one female, Santa Rita Mts., Ariz., June 11, 1898. B. A. Schwarz.

Life history. Unknown.

Remarks. This species might be confused with *Negalasa rubralis* at first glance. Distinguishing characters are the fuscous antemedial and postmedial lines on the costa, generally lighter coloration, and the longer, more narrow forewings. The distinctness of the median band is variable.

Penthesilea **Ragonot, 1891**

http://species-id.net/wiki/Penthesilea
Figs 4, 14–16

Penthesilea Ragonot, 1891: 493.

Type species. *Penthesilea sacculalis* Ragonot, by monotypy.

Description. Head. Labial palpus decumbent; length of male palpus nearly equal to head width, length of female palpus longer than head width; maxillary palpus vestigial; proboscis moderately well-developed; frons rounded with vestiture extended

obliquely; vertex smooth-scaled; occiput rough-scaled; eye large; ocellus separated from base of antenna by scales; without a chaetosema.

Thorax. Forewing broad and arched at base, apex broadly rounded, outer margin and anal angle broadly rounded; sexually dimorphic; male with a tympanic vesicle at base of costa, with a large hair-pencil gland as in *Salobrena*; female without a glandular vesicle; both sexes with Sc long, intercepting costa past one-half length; R_1 and R_2 separate; R_3 and R_4 stalked, R_5 from stem; M_1 from end of discal cell just below anterior angle; M_2 and M_3 separate and arising from posterior angle of discal cell; Cu_1 and Cu_2 separate and arising from below posterior angle of cell; 1A absent, 2A and 3A separate at base but briefly anastomosed a short distance distad; retinaculum of male loop-shaped and strongly developed with inner surface corrugated as in *Salobrena*, *Clydonopteron*, *Satole* and *Tosale*. Hind wing of male with frenulum stoutly developed with a short hook at base, female normal; Sc arched at base and anastomosed with Rs past end of discal cell; M_1 arising from anterior angle of discal cell; M_2 and M_3 separate, arising from the posterior angle of discal cell; Cu_1 and Cu_2 separate, from before the posterior angle of the discal cell. Legs with scale tufts on mid and hind tibia.

Abdomen. Short and stout; male with a small lateral pleurite on the terminal segment bearing a tuft of scales as in *Tosale* and *Salobrena*.

Male genitalia. Uncus narrow, dorsally setose, aculeate with apex rounded, base with arms produced for articulation with gnathos, tips broadly rounded; vinculum narrow, saccus not produced anteriad; gnathos apex aculeate, gently curved dorsad, arms gradually expanded to broad articulation with modified pedunculus and base of uncus; valva narrow, tips directed slightly upward and mediad, sacculus without a clasping process; transtilla moderately developed and incomplete; juxta trapezoidal, dorsal margin concave; phallus slightly curved upward, proximal end slightly expanded, coecum small, without a cornutus.

Female genitalia. Ovipositor moderately short, apex of papillae anales unilobate; anterior apophysis slightly longer than posterior apophysis; lamella postvaginalis triangulate; anterior margin of eighth tergite rounded; ostium bursae membranous; a sclerotized constriction below antrum on ductus seminalis as in *Tosale*; inception of ductus seminalis at junction of ductus bursae and corpus bursae; corpus bursae without a signum.

Remarks. The genera *Penthesilea* and *Tosale* are closely related. The female genitalia have a membranous ostium bursae, a short sclerotized constriction on the ductus bursae, and the inception of the ductus seminalis at the junction of the ductus bursae and ostium bursae are common to both genera. *Tosale* differs in having the anterior margin of the eighth tergite heavily sclerotized. The male genitalia show more divergence. The uncus and valva of *Penthesilea* are more narrow than in *Tosale* and the saccus is not produced. Both genera have small lateral pleurites on the hind margin of the last abdominal segment of the male for support of lateral scale tufts. The venation indicates the *Tosale* is more specialized, with stalking of R_2, R_3, R_4, and R_5 in the forewing. The forewing of *Penthesilea* has R_2 free with R_3 and R_4 stalked and R_5 short-stalked. Both genera have M_1 widely separately from the stem of R_5.

***Penthesilea sacculalis sacculalis* Ragonot, 1891, revised status**
http://species-id.net/wiki/Penthesilea_sacculalis_sacculalis

Penthesilea sacculalis Ragonot, 1891: 493.

Description. Alar expanse. 13 to 16 mm.

Head. Labial palpus dark brown with black; frons and vertex dark brown with white around the base of scape; occiput reddish-brown.

Thorax. Brown dorsad and ventrad. Forewing dark brown to fuscus; basal angle occasionally overscaled with reddish-brown, base darker than distal part; antemedial line white and slightly excurved; a yellow suffusion distad of white antemedial line; postmedial line white with a large brownish-orange suffusion near the costa, acutely excurved mediad; fringe fuscous. Hind wing dark brown to fuscous; Cu_2 with a small white spot near outer margin, a small reddish-brown dash along Cu_2 anteriad and posteriad to spot; fringe fuscous. Legs dark brown to fuscous; midtarsi white, hind tarsi white except first subsegment fuscous.

Abdomen. Brown overscaled with fuscous and reddish-brown, lateral tufts fuscous.

Genitalia. As described for genus.

Type data. One male holotype, with no locality data is in the Museum National D'Histoire Naturalle in Paris.

Material examined. Six males and eleven females from the following localities:

UNITED STATES: FLORIDA: Coconut Grove (USNM); Lake Placid, Archbold Bio. Sta., May (USNM); Royal Palm State Park (USNM); Winer Park [Winter Park?] (AMNH). GEORGIA: Atlanta (USNM). LOUISIANA: Lafayette, June (AMNH). NORTH CAROLINA: Southern Pines, July, Aug. (USNM). TEXAS: Brownsville (USNM); San Benito, July, Sept. (USNM). VIRGINIA: Skyland, July (USNM).

Life history. Unknown.

Remarks. Ragonot (1891) states that the type specimen is probably from North America. Of the specimens that I have examined, it more nearly matches the specimens from Florida. The specimens from Florida are darker and smaller than those from Louisiana, Texas, Georgia, and North Carolina.

***Penthesilea sacculalis baboquivariensis* Cashatt, subsp. n.**
http://species-id.net/wiki/Penthesilea_sacculalis_baboquivariensis
Figs 4, 14–16

Description. Alar expanse. 13 to 17 mm.

Head. Labial palpus dark pinkish-brown; frons, vertex, occiput, and antenna pinkish-brown.

Thorax. Upper and lower surfaces pinkish-brown. Forewing same as the nominate species except pinkish-brown. Hind wing pinkish-brown occasionally with a small white spot as in *sacculalis*, but with no dark scaling anteriad or posteriad. Legs dark pinkish-brown with mid and hind tarsi white.

Abdomen. Pinkish-brown with terminal scale tufts pinkish-brown.

Genitalia. As described for the genus.

Type data. The holotype, allotype, and forty-four paratypes are from the Baboquivari Mts., Pima Co., Arizona. The male holotype and female allotype are in the USNM. The male holotype is from Baboquivari Mts., Pima Co., Arizona, August 15-30, 1923, O. C. Poling, is labeled as the holotype, and the female allotype is labeled, August, 1924, O. C. Poling. The paratypes are labeled as follows: UNITED STATES: ARIZONA: two males and two females, elevation approximately 5000 ft., June 15-30, 1923 (USNM); one female, July 1–15, 1924, O. C. Poling (USNM); one female, July 15–30, 1924, O. C. Poling (USNM); two females, Aug. 1–15, 1924, O. C. Poling (USNM); one male and four females, Aug. 15–30, 1923, O. C. Poling (USNM); one male Aug., (USNM); three males and ten females, Sept. 1-15, 1923, 1924; O. C. Poling (USNM); one male and one female, Sept. 15–30, 1924, O. C. Poling (USNM); one male and four females, Oct. 1–15, 1923, O. C. Poling (USNM); one male and one female, Oct. 15–30, 1924, O. C. Poling (USNM); three males and two females, Sabino Canyon, Sept. 5-6, 1951, L. M. Martin (CNC); one male and one female, Sabino Canyon, Sept. 5, 1951, R. J. Ford (CNC).

Life history. Unknown.

Remarks. This subspecies differs from the nominal species only by the pinkish-brown coloration.

Acknowledgments

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Description and ecology of two new species of *Gyronotus* van Lansberge, 1874 (Coleoptera, Scarabaeidae) from southern Africa

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Abstract

Recent collections in KwaZulu-Natal and Swaziland have led to the discovery of two new species of the flightless and highly threatened Scarabaeinae genus *Gyronotus* van Lansberge, 1874. A description of *G. perissinottoi* **sp. n.** and *G. schuelei* **sp. n.** is provided here, along with notes on their habitat and ecology. Unlike the vast majority of the species previously known in the genus, which have been reported as forest dwellers, the two new species are found during daytime in grassland/savanna vegetation, at the margin of forest patches.

Keywords

Scarabaeinae, new species, threatened genus, South Africa, Swaziland, montane grassland, sour bushveld, coastal sourveld

Introduction

The genus *Gyronotus* currently includes six species, subdivided into three species groups on the basis of their biogeographic distribution, body shape and structure of male genitalia (Davis et al. 2008). They are all wingless, with fused elytra, and are regarded among the most endangered of the African Scarabaeinae because of their sensitivity to disturbance. All species described so far, apart from *G. glabrosus* which is an upland grassland dweller (A. Davis pers. comm.), are linked to coastal and low-lying forest habitats, which have undergone massive transformation during the past 50–100 years, through clearance, degradation and fragmentation (Davis et al. 1999, Mucina and Rutherford 2006). *G. fimetarius* Kolbe, 1894, and *G. carinatus* Felsche, 1911, have disappeared from large parts of their original distribution range, namely the East Usambara Mountains of Tanzania and south of Maphelane in KwaZulu-Natal, respectively (Davis et al. 2008).

On the basis of the wide gaps existing between the distribution ranges of the species currently described, Davis et al. (2008) correctly predicted that new records and species would be discovered in the future. Here, we report on two new species that have only recently being recognised and collected in sufficient number to warrant their description. In the case of *G. perissinottoi* sp. n., ecological observations have also been possible, through repeated survey exercises. This species occurs in a small but biodiversity unique area in southern KwaZulu-Natal. The first female specimen was collected already in 2004 and a second one in 2007, but it was only in January 2013 that a full series including males was finally secured, through intense search and trapping efforts. The second species, *G. schuelei* sp. n., originates from western Swaziland and is currently known only from two specimens, one male and one female, collected in different places and on separate occasions.

Methods

As part of the collecting efforts, ground traps baited with fresh baboon dung were deployed in the Umthamvuna Reserve during December 2012 and January 2013. Traps consisted of 600 ml plastic jars of 80 mm mouth diameter and 120 mm height buried in the soil with the top levelled with the ground. They were checked at regular intervals of 2–5 days and after each visit traps were first emptied and then re-supplied with fresh dung.

The description of morphological characters follows the terminology used by Davis et al. (1999). Specimen length was measured from the anterior margin of the clypeus to the apex of the pygidium. Specimen width represents the maximum width of the elytra. Photos of the holotypes and allotypes were taken using a Canon EOS 400D camera fitted with a Canon MP-E 65 mm objective. Photos were processed with photo stacking technique, using Combine ZP (freeware free software by Alan Hadley, http://www.hadleyweb.pwp.blueyonder.co.uk). The first author compiled the taxonomic

part of this study, including the descriptions of the new species. The second author collected all the specimens, with one exception, and contributed all habitat description and ecological observations.

Collections are abbreviated as follows: TMSA, Ditsong National Museum of Natural History (formerly Transvaal Museum), Pretoria, South Africa; ISAM, Iziko South African Museum, Cape Town, South Africa; PMOC, Collection Philippe Moretto, Toulon, France; PCRP, Private Collection R. Perissinotto & L. Clennell, Port Elizabeth, South Africa. Geographical abbreviations are as follows: KZN, KwaZulu-Natal Province, South Africa; SWA, Swaziland.

Taxonomic account

***Gyronotus perissinottoi* Moretto, sp. n.**
http://zoobank.org/652366C0-B9E4-4526-B217-BB757A0EB0CF
http://species-id.net/wiki/Gyronotus_perissinottoi
Figures 1, 3

Type locality. South Africa, KwaZulu-Natal, Umthamvuna Nature Reserve, Beacon Hill Section (31°00'47"S; 30°10'23"E); on escarpment at the edge of riverine forest, in grassland interspersed with rocky outcrops and boulders.

Type specimens. Holotype ♂: South Africa, KZN, Umthamvuna Reserve, 13.I.2013, ground trap baited with baboon dung, R Perissinotto & L Clennell legit (TMSA). Allotype ♀: same data as above (TMSA). Paratypes, 3♂ 4♀: same data as above (ISAM, PCPR, PMOC). 1 ♀, same locality and collectors, but 24.I.2004 (PMOC); 1 ♀, same locality and collectors, but 28.I.2007 (PMOC).

Diagnosis. *Gyronotus perissinottoi* sp. n. is, with *G. dispar* Felsche, 1911, one of the largest *Gyronotus* species currently known. In contrast to all the other species, including *G. marginatus* Péringuey, 1888, currently synonymized with *G. pumilus* (Boheman, 1857), the elytra are punctate and the interstriae very marked. Another typical character is the brush of long, flat-laying, yellow setae that cover a narrow area along the middle of the posterior side of the mesofemora in the male. The shape of the parameres is also unique, and closest to that of *G. pumilus* (*sensu* Scholtz and Howden 1987), with parameres flattened laterally and crossing each other.

Etymology. This species is named after Renzo Perissinotto, who collected the entire type series and compiled the ecological notes reported in this work.

Description. Length 16–18 mm, width 9–10.5 mm; body convex, rounded, shining bronze with metallic reflections, glabrous on the upper side; with few inconspicuous setae on the posterior quarter of elytra in very fresh specimens.

Head. Entirely, densely and finely punctate, except the anterior part of the clypeus which is sparsely and very finely dotted; clypeo-genal suture faint; only short segment of occipital suture present on each side of the head, reaching the extremity of the clypeo-genal suture.

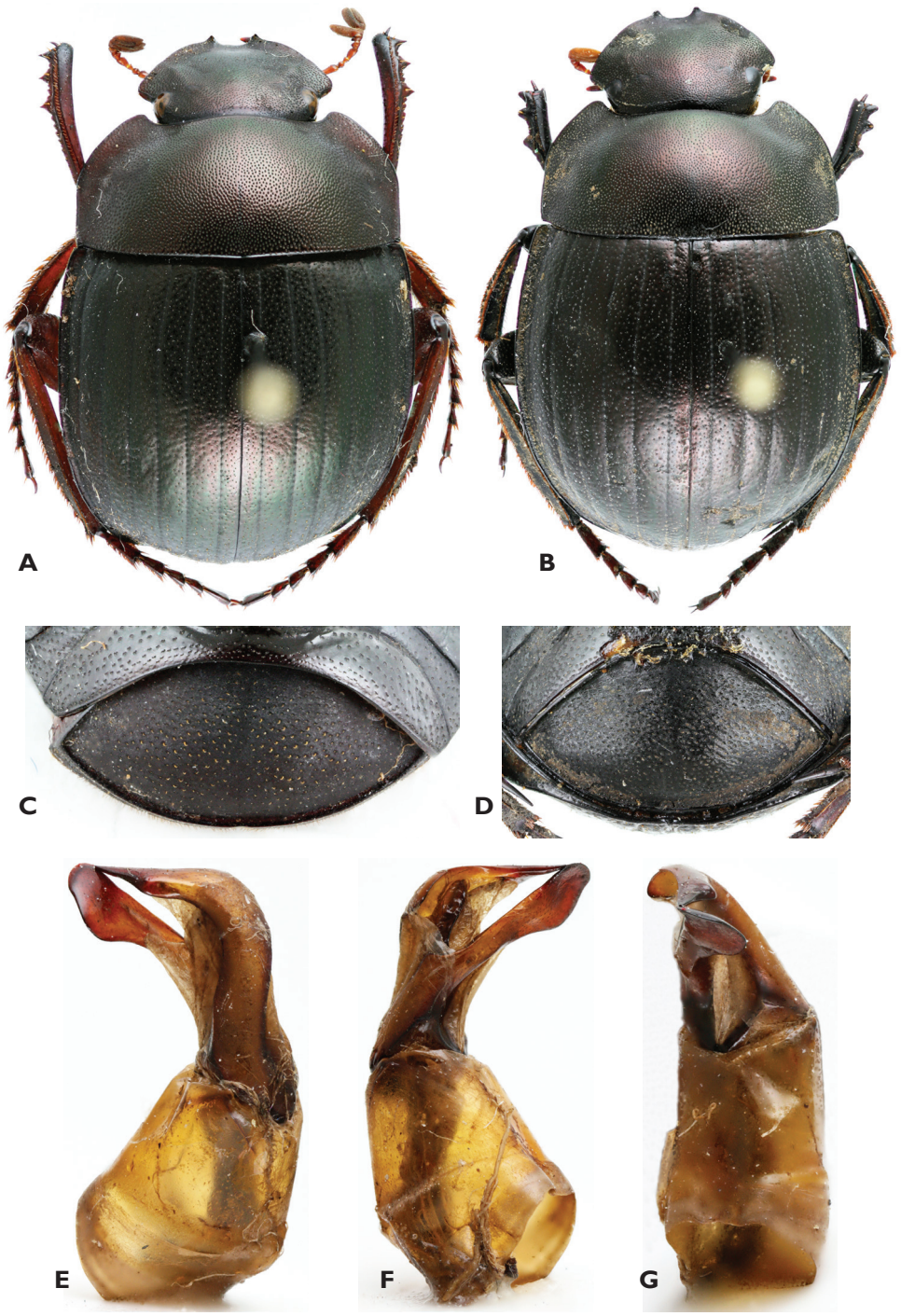

Figure 1. *Gyronotus perissinottoi* sp. n. **A** Holotype male, dorsal habitus **B** Allotype female, dorsal habitus **C** Male pygidium, ventral side **D** Female pygidium, ventral side **E** left **F** right and **G** ventral sides of aedeagus. Photo: Mickaël François.

Thorax. Entirely, densely and finely punctate, with punctures finer anteriorly and larger laterally. Lateral angle at middle of sides widely rounded; mesosternum strongly punctate near the suture and in the middle, but finely punctate laterally; metasternum shiny and very finely punctate in the middle part, shagreened and more strongly punctate laterally, with punctures elongated; internal end of male protibia broadened, densely fringed at apex with very short setae, mobile spur short and directed obliquely outwards; female protibia with sharp tooth at the apex of the inner border, mobile spur about twice as long as in the male and directed forward; femora densely punctate; brush of long, flat-laying, yellow setae covering a narrow area along the middle of the posterior side of the mesofemora in male (Figure 1A); brush of setae absent in female (Figure 1B).

Elytra. Regularly and strongly convex dorsally, slightly convex laterally; striae obsolete, but densely and strongly punctate, visible with naked eye; interstriae slightly convex, sparsely and finely punctate, with punctures of different size on a very finely shagreened tegument, interspersed with very small, flat and shiny granules.

Abdomen. Sternites smooth, finely punctate medially, stronger laterally; pygidium convex, strongly shagreened, strongly and very densely punctate in females, but sparsely and finely with punctures elongated in males; parameres of aedeagus asymmetrical (Figures 1E–G).

Remarks. It was previously known that *Gyronotus pumilus* also occurs in the Umthamvuna Nature Reserve (Davis et al. 2008; pers. observ.). However, the two species occupy different habitats, with *G. pumilus* restricted to the riverine forest and *G. perissinottoi* to the grassland plateau, outside the forest.

***Gyronotus schuelei* Moretto, sp. n.**
http://zoobank.org/8C6B0DE7-D83F-42A3-A35F-FD5EB536A18C
http://species-id.net/wiki/Gyronotus_schuelei
Figures 2

Type locality. Western Swaziland (26°08'18"–26°29'33"S; 31°08'13"–31°11'02"E); in mountain grassland with pockets of sour bushveld.

Type specimens. Holotype ♂: Swaziland, Mlilwane, 28.III.1997, R. Perissinotto & L. Clennell legit (PMOC). Allotype ♀: 19/20.XI.2001, Swaziland, Malolotja Nature Reserve, P. Schüle legit (PMOC).

Diagnosis. This species shows its closest affinity to *G. glabrosus* Scholtz & Howden, 1987 (p. 84, fig. 3), with which it shares the same structure of the parameres, although their shape is clearly different. In particular, the right paramere is much slender and more regularly curved than its left counterpart, while the apical plate of the left paramere is larger than that on the right.

Etymology. This species is dedicated to Peter Schüle, German specialist of Cicindelidae, who collected the allotype specimen.

Description. Length 14 mm, width 8.5 mm; body moderately convex, very dark brown, with few short, erected, white setae on the posterior half of the elytra.

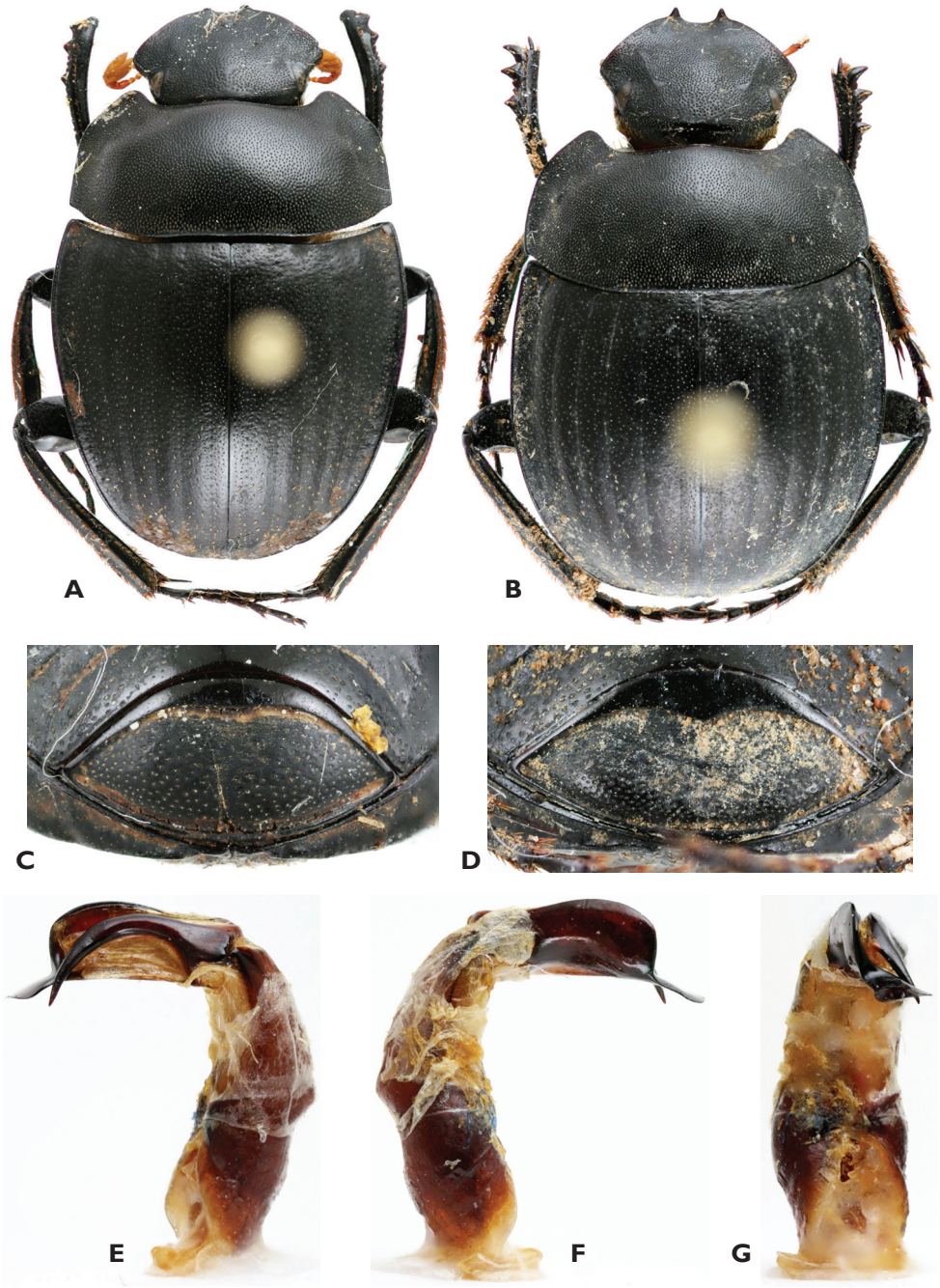

Figure 2. *Gyronotus schuelei* sp. n. **A** Holotype male, dorsal habitus **B** Allotype female, dorsal habitus **C** Male pygidium, ventral side **D** Female pygidium, ventral side **E** left **F** right and **G** ventral sides of aedeagus. Photo: Mickaël François.

Figure 3. *Gyronotus perissinottoi* sp. n. in its natural habitat at the Umthamvuna Nature Reserve. Photo: Lynette Clennell.

Head. Entirely, densely and finely punctate except for a small space between the clypeal teeth, which is finely dotted.

Thorax. Entirely, densely and very finely punctate; exhibiting lateral angle before the middle of the sides; mesosternum strongly but sparsely punctate; metasternum shiny, very finely and sparsely punctate; profemur densely punctuate; mesofemur punctate in the middle, sparsely dotted distally and apically; metafemur sparsely dotted distally, densely punctuate apically.

Elytra. Striae obsolete on the disc, more distinct on the sides, finely punctate; interstriae flat on the disc, more convex apically and laterally, finely punctate.

Abdomen. Pygidium convex in male, totally inflexed in ventral position in female; with raising contour at margin, particularly enlarged at apex in male (Figure 2C), very enlarged in female (Figure 2D); parameres of aedeagus asymmetrical (Figures 2E–G).

Remarks. This appears to be the first record of the presence of *Gyronotus* in Swaziland. Its distribution range needs to be investigated further, as it may include adjacent mountainous areas in the Mpumalanga Province of South Africa.

Discussion

The genus *Gyronotus* is part of the tribe Canthonini, which has long been recognised as a Gondwanaland relict (Halffter 1974; Davis et al. 1999). Members of the genus are also wingless and particularly vulnerable to environmental disturbance (Davis et al. 2008). Thus, they are undoubtedly of substantial biodiversity and conservation value, with status ranging from vulnerable to critically endangered (Davis et al. 1999). Much of their recent demise has been attributed to the rapid disappearance of their predominantly forest habitats (Low and Rebelo 1996; Mucina and Rutherford 2006). Indeed, five of the six species described prior to this study are regarded as strictly forest specialists, occurring in coastal and low-lying montane forests on the seaboard of southern and east Africa (Davis et al. 2008).

The two new species described here, *G. perissinottoi* sp. n. and *G. schuelei* sp. n., together with *G. glabrosus*, are actually grassland or savanna inhabitants. The first is found exclusively in open coastal sourveld with scattered shrubs and small trees, on the plateau and escarpment just above the scarp forest that characterise the Umthamvuna River Gorge, at altitudes of 300–400 m (Figures 3–4). According to the classification scheme of Mucina and Rutherford (2006), this is part of vegetation unit CB4 known as Pondoland-Ugu sandstone coastal sourveld. This is a grassland type that, while exhibiting a large plant diversity and several local endemics, is also among the six most vulnerable vegetation units in South Africa (Mucina and Rutherford 2006). The scarp forest just below, within the gorge, constitutes the typical habitat of *G. pumilus*.

The Mlilwane and Malolotja reserves of western Swaziland, where *G. shuelei* sp. n. has been recorded so far, are higher altitude (700–1500 m) hilly areas (Figure 5) that exhibit vegetation units of the KaNgwane montane grassland and Swaziland sour bushveld types, coded respectively Gm 16 and SVI 14 in Mucina and Rutherford (2006). Here, the short and closed grassland layer includes many forbs and scattered shrubs on and around the rocky outcrops. The savanna component consists of a generally open, medium-tall tree layer over a closed, well-developed grass layer. These vegetation units are only regarded as "vulnerable" at present, as a reasonable proportion of the total area is under statutory conservation but much of the remaining part has already been converted to plantations of alien trees or cultivation (Mucina and Rutherford 2006).

Concerning food exploitation, at Umthamvuna *G. perissinottoi* sp. n. appears to rely mainly on Chacma baboon (*Papio hamadryas*) dung, while *G. pumilus* inside the forest is regularly observed in or on bushpig (*Potamochoerus larvatus*) dung (RP pers. observ.). The vast majority of *G. perissinottoi* sp. n. specimens were trapped among rock boulders and outcrops scattered within the grassland, suggesting the possibility that adults may actually prefer to hide dung pellets with eggs under rocks or in crevices, rather than bury them deep into the soil.

No information was unfortunately collected regarding food preferences in *G. schuelei* sp. n., but the specimen collected at Mlilwane was found during daytime on unidentified herbivore dung. Davis et al. (2008) suggested that species of the

Figure 4. *Gyronotus perissinottoi* sp. n. Typical habitat in the escarpment grassland at the margin of the riverine forest (Umthamvuna Nature Reserve, South Africa). Photo: Lynette Clennell.

Figure 5. *Gyronotus schuelei* sp. n. Typical habitat in montane grassland interspersed with bushveld pockets (Mlilwane Nature Reserve, Swaziland). Photo: Lynette Clennell.

genus *Gyronotus* may be day-active. This is confirmed by observations made during the present study, as both species described here as well as *G. pumilus* were collected while active on the ground during daytime.

Acknowledgements

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