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THREE NEW SPECIES OF *TYLOPERLA* SIVEC & STARK (PLECOPTERA: PERLIDAE) FROM INDIA

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ABSTRACT

Three new species of *Tyloperla* Sivec & Stark are proposed from specimens collected in Karnataka, Maharashtra and Himachal Pradesh states, India. The new species are compared with other members of the genus, a key for species known from the Indian subcontinent is presented, and an updated checklist of *Tyloperla* species is given.

Keywords: Plecoptera, Perlidae, *Tyloperla*, new species, India

INTRODUCTION

Tyloperla is a small genus of Asian stoneflies which currently includes 12 species (Cao & Bae 2007; Du 2007; Sivec et al. 1988; Stark & Sivec 1991; 2005; Yang & Yang 1993). One of these, *T. bihypodroma* Du, 2007 is not included in the DeWalt et al. (2013) list. Most species are known from few specimens and appear to be rare in collections. Males of known species have moderately long, acute hemitergal processes with a small basal callus; patches of sensilla basiconica may occur on terga 7-9 and hair brushes typically occur on some combination of the metasternum and abdominal sterna 4-7. Several species have a small mesal lobe on tergum 8 (Sivec et al. 1988; Stark & Sivec 1991; 2005), and several have spiny subapical or lateral lobes on the aedeagal sac. Adults and larvae of known species are moderately sized perlids with three ocelli.

The current study is based on specimens from the Agumbe Ghats in Karnataka State, India, from Amboli in the adjacent state of Maharashtra, and from a pair of specimens collected in Barog, Himachal Pradesh State. Specimens from Agumbe Ghats and Amboli were included in a small collection of specimens forwarded from the Monte L. Bean Life Science Museum, Brigham Young University, and appear to represent two previously undescribed species. The specimens from Himachal Pradesh State are similar to several other members of the genus, and also appear to represent a previously unrecognized species. Prior to this study only one species of *Tyloperla* was known from India, with most species recorded from Southeast Asia (Table 1). The formal descriptions presented herein increase the number of Indian *Tyloperla* species to four.

MATERIALS AND METHODS

The genitalic structures of male specimens were prepared for examination using the cold maceration technique of Zwick (1983), and females were prepared by boiling the terminalia in 10% KOH. Both were documented with drawings made using stereomicroscopes equipped with drawing tubes. Eggs were examined with an Amray 1810d scanning electron microscope using the techniques of Stark & Green (2011). The holotypes are deposited in the United States National Museum of Natural History, Washington, D.C. (USNM), through the courtesy of the Monte L. Bean Life Science Museum, Brigham Young University, Provo, Utah (BYUC), or in the Slovenian Museum of Natural History, Ljubljana, Slovenia (PMSL). Paratypes are deposited in the Monte L. Bean Life Science Museum, Brigham Young University, Provo, Utah (BYUC), or in the Slovenian Museum of Natural History, Ljubljana, Slovenia (PMSL).

RESULTS AND DISCUSSION

Tyloperla agumbe sp. n. (Figs. 1-12)

Material examined. Holotype ♂, **India**, Karnataka, Agumbe Ghats, 13° 29.386'N, 75° 04.537'E, 9 October 2004, G. Svenson (USNM). Paratypes: **India**, Same site as holotype specimen but 11 October 2004, canopy light trap, G. Svenson, 1♂ (BYUC). Maharashtra, Amboli, 15° 55.843'N, 73° 57.836'E, 3 October 2004, Svenson, Cameron, Miller, 9♂, 6♀ (BYUC).

Adult habitus. General color brown, patterned with pale brown. Dorsum of head covered with moderately dense patch of upright, long, brown hair; head mostly pale but with darker areas between ocelli; lappets and basal antennal segment pale (Fig. 1). Pronotum with narrow median yellow band and wider lateral pale band; disc mostly brown or pale brown, reflexed margin bearing a dark brown band. Wings amber, veins darker except for pale C vein. Femora pale except narrow, dark brown band at distal tips, tibiae dark brown.

Male. Forewings ca. 13-14.5 mm long. Abdominal sterna 6-8 bearing mesal patches of short, thick sensilla basiconica; sternum 8 with ca. 20 in scattered patch, sternum 7 bearing a low, posteromedian

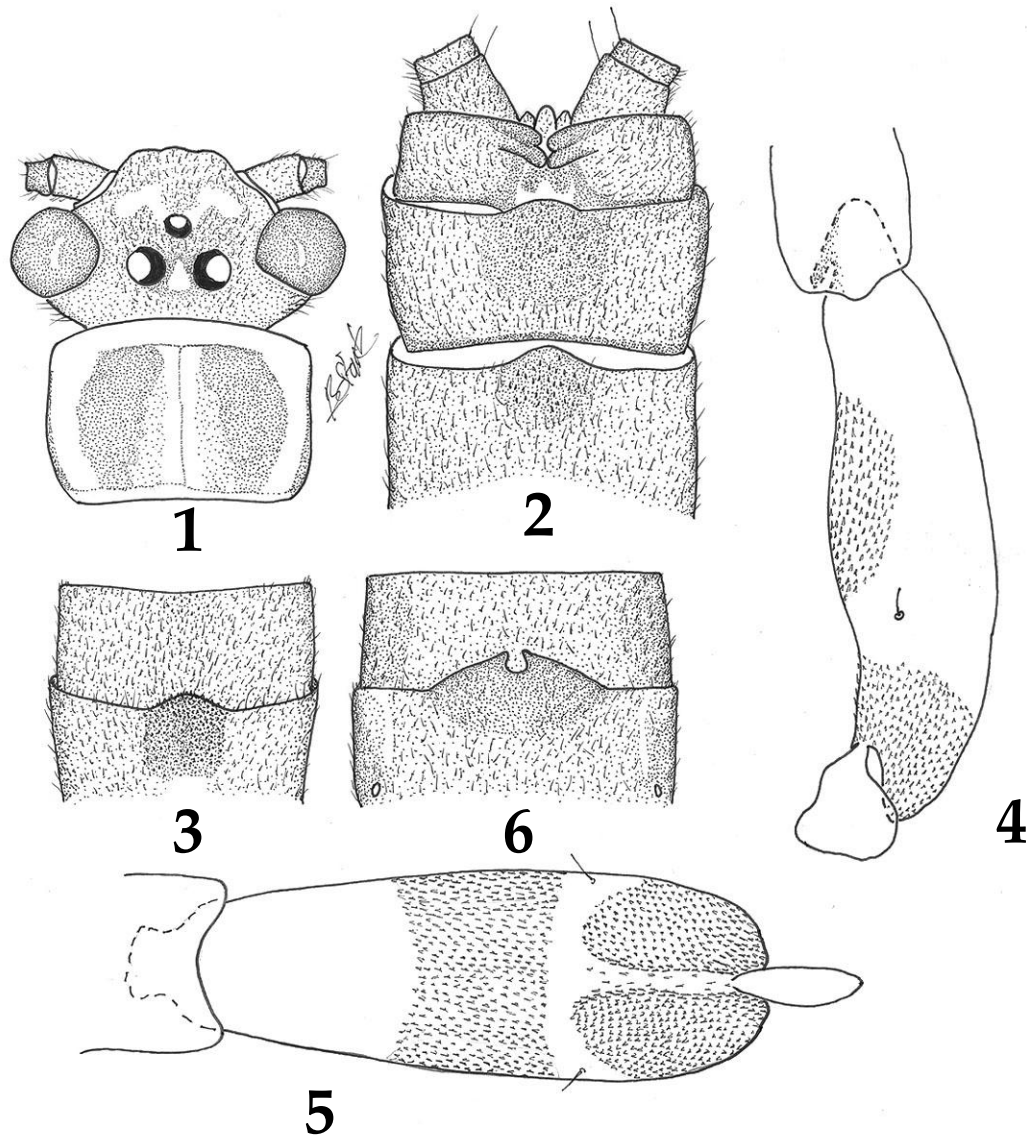
tubercle covered rather densely with sensilla basiconica which extend to anterior third of segment in a more scattered patch (Fig. 3), sternum 6 with only a few (ca. 4-5) sensilla basiconica in a marginal patch, sterna 8-9 without sensilla basiconica. Hemiterga with a well-developed basal callus and a short anterior process which reaches far short of tergum 9; a small arc of sensilla basiconica occurs between hemiterga on tergum 10 (Fig. 2); terga 8-9 each with a small mesal lobe covered with sensilla basiconica. Aedeagus without spiny lobes; tube and sac in lateral aspect curved gradually ventrad and bearing a ventromedian saddle of moderately long spines, and a subapical ring of short, thick, spines (Fig. 4); subapical ring interrupted by a longitudinal median groove in which few spines occur, and from which a small membranous bag-like structure is everted (Fig. 5). A single seta occurs on each side between ventral saddle of spines and subapical ring (Fig. 5).

Female. Forewing length 16-17 mm. Subgenital plate on sternum 8 triangular in outline, projecting over about 1/3 of sternum 9, and bearing a small U-shaped mesal notch (Fig. 6). U-shaped region surrounding notch hairless; plate darker than background pigment of segment. Width of plate at base ca. 1/2 of sternal width.

Egg. Outline almost spherical (Fig. 7). Length ca. 335 µm, equatorial width ca. 328 µm. Collar short and wide, width ca. 89 µm, rim not distinctly flanged, sides bearing ca. 11 vertical ridges in lateral aspect (Fig. 10). Anchor a thin, umbrella-shaped structure with short pedicel, an irregular margin and apparently few surface globular bodies (Fig. 8). Chorion covered throughout with mostly pentagonal and hexagonal follicle cell impressions (Figs. 9-12); walls consist of six low, rounded tubercles set at FCI angles, forming cells ca. 27 µm across; most FCI floors contain a single central and six, fine submarginal aeropyles, but some contain 8-9 aeropyles and the central one may sometimes be displaced (Fig. 9). FCI's on lid have tubercles more tightly grouped and slightly larger than those nearer the equatorial region (Fig. 11). Subequatorial eclosion ring distinct, surface of ring smooth and ca. 12 µm wide (Fig. 12). Micropyles not detected.

Larva. Unknown.

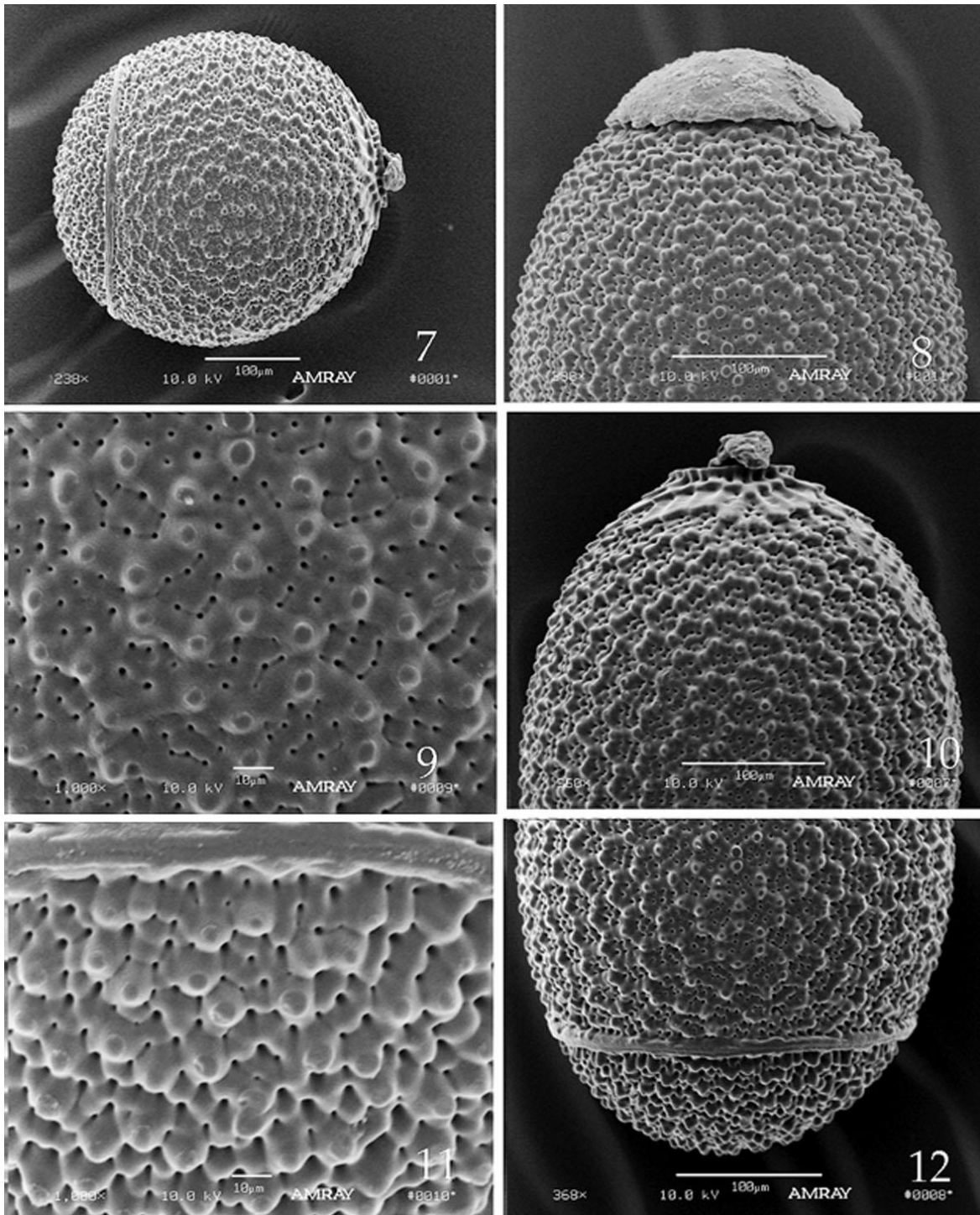
Etymology. The species name, based on the type locality, is used as a noun in apposition.



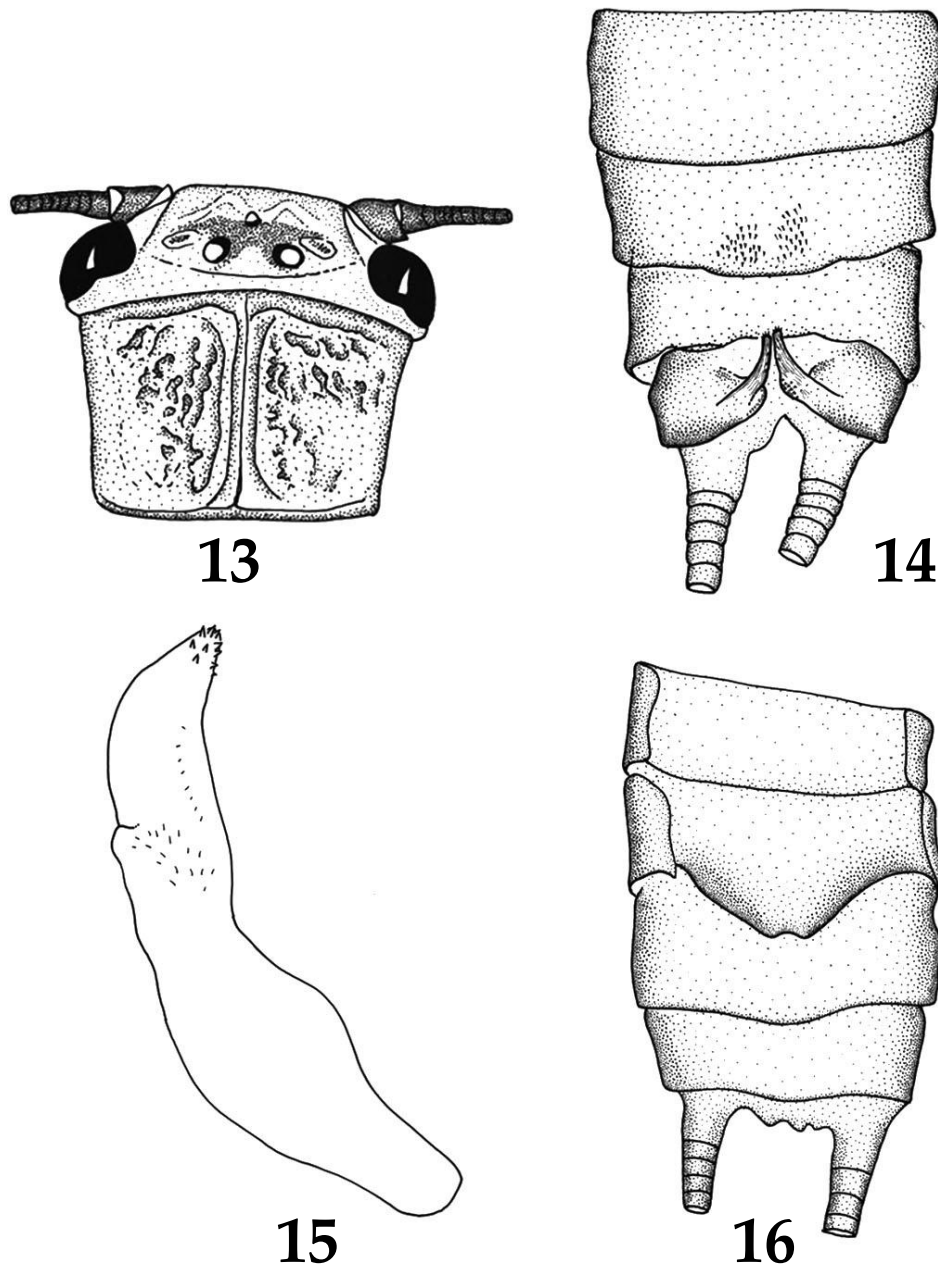
Figs. 1-6. *Tyloperla agumbe* structures. 1. Head and pronotum. 2. Male terminalia, dorsal. 3. Male abdominal sterna 7-8. 4. Aedeagus, lateral. 5. Aedeagus, ventral. 6. Female subgenital plate.

Diagnosis. The short hemitergal lobes and median sclerite with sensilla basiconica on tergum 10 are features unique to this species and *T. karnataka* sp. n. among known *Tyloperla*; males of the two are distinguished on the basis of the presence of a prominent lobe on sternum 7 in *T. agumbe*. The female subgenital plate, reaching near midlength of sternum 9, is somewhat shorter than that of

previously described species, and the egg is generally similar to those of *T. courtneyi* Stark & Sivec, *T. karnataka* (see below), *T. khang* Stark & Sivec and *T. trui* Cao & Bae in having a distinct eclosion ring and prominent FCI's over the entire egg (Cao & Bae 2007; Stark & Sivec 2005). A more complete diagnosis is given below under *T. karnataka*.



Figs. 7-12. *Tyloperla agumbe* egg structures. 7. Entire egg, lateral aspect. 8. Collar end with anchor. 9. Chorionic detail, equatorial zone. 10. Collar end with most of anchor removed. 11. Chorionic detail, lid. 12. Equatorial zone, eclosion line and lid.



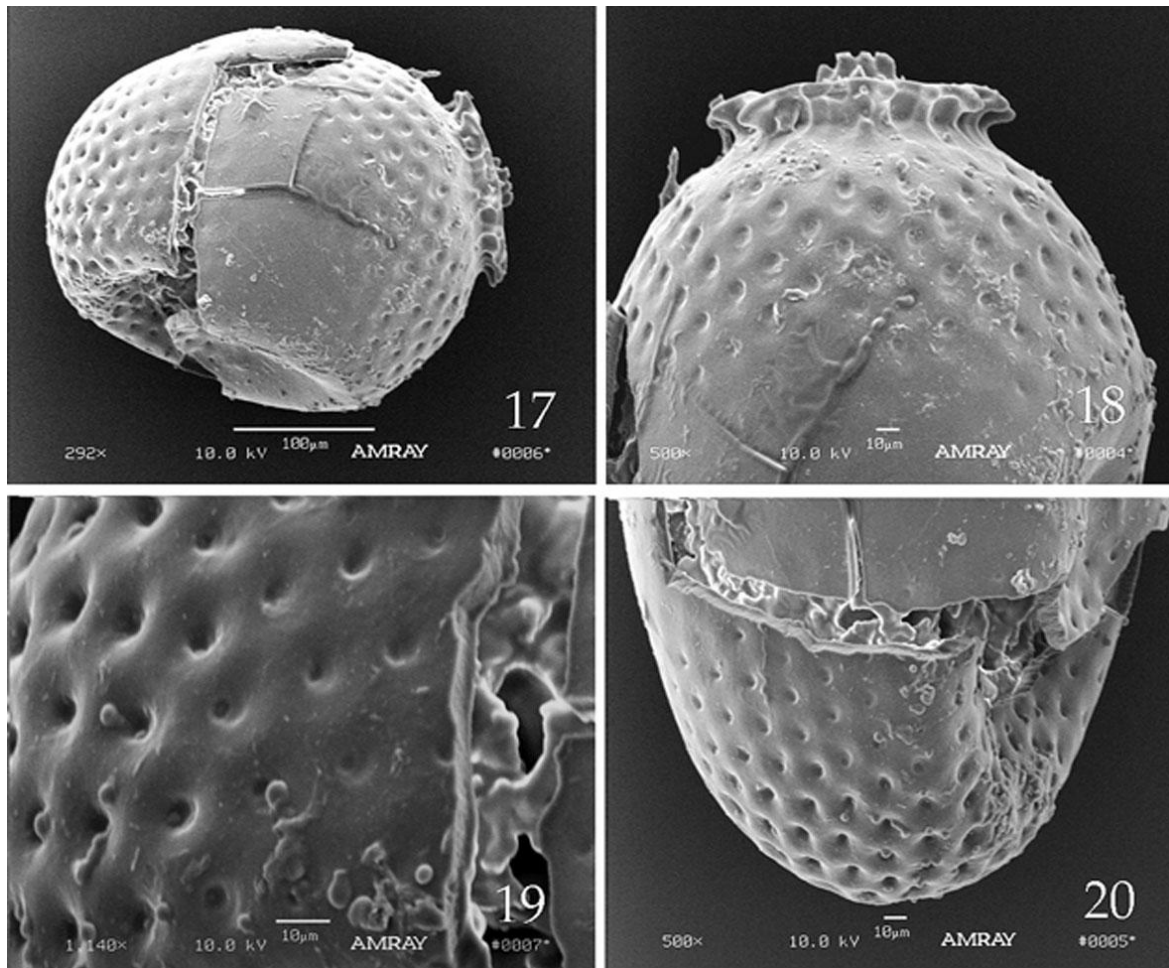
Figs. 13-16. *Tyloperla barog* structures. 13. Head and pronotum. 14. Male terminalia, dorsal. 15. Aedeagus, lateral. 16. Female terminalia, ventral.

***Tyloperla barog* sp. n.**
(Figs. 13-20)

Material examined. Holotype ♂ and 1 ♀ paratype, **India**, Himachal Pradesh, Barog, Solan District, 1550

m, 17 July 1992, J.M. Julka, B. Bala (PMSL).

Adult habitus. General color brown, patterned with yellow-brown. Head with an area of dark brown pigment between ocelli which extends to anterior ocellus and laterally, forward of callosities; lappets



Figs. 17-20. *Tyloperla barog* egg structures. 17. Entire egg, lateral aspect. 18. Collar end. 19. Chorionic detail, lid. 20. Lid.

without dark pigment, antennae brown (Fig. 13). Pronotum with pale brown pigment over most of disc, but with a narrow, pale median band and numerous rugosities.

Male. Forewing length 19 mm. Abdominal sterna 4–7 bearing hair brushes. Hemiterga with well developed, oval basal callus bearing small sensilla basiconica on inner margins (Fig. 14); anterior process of hemiterga slender, tapered to a rounded apex and bearing a few sensilla scattered along the dorsoapical surface. Tergum 9 unmodified, tergum 8 with a small mesal projection and a median patch of numerous sensilla basiconica. Aedeagus armed with a few, relatively large apical spines and thin setal-like spines form a row along the ventrolateral margin of

the sac and a small patch near the ventrolateral margin of the tube; tube mostly membranous and swollen near midlength (Fig. 15).

Female. Forewing length 23 mm. Subgenital plate on sternum 8 projecting over about half of sternum 9, triangular with a small median notch (Fig. 16).

Egg. Outline oval. Length ca. 320 µm, equatorial width ca. 265 µm (Fig. 17). Collar short, height ca. 20 µm, width ca. 139 µm; rim of collar flanged and irregularly incised, sides bearing ca. 8 vertical ridges in lateral aspect (Fig. 18). Surface coarsely pitted in a broad zone ca. 124 µ wide surrounding collar (Figs. 17-20) and in a similar zone ca. 96 µ wide on lid (Fig. 20); equatorial zone without pits (Fig. 17). Eclosion ring absent. Micropyles not observed. Only

three poorly cleaned and broken eggs were suitable for SEM study.

Larva. Unknown.

Etymology. The species name, based on the type locality, is used as a noun in apposition.

Diagnosis. This species is generally similar in hemitergal structure to *T. attenuata* (Wu & Claassen) and *T. schmidi* Stark & Sivec, but differs from both in lacking a sensilla basiconica patch on tergum 9 (Wu & Claassen 1934; Stark & Sivec 1991). In addition, the new species may be separated from *T. attenuata* by the acute hemitergal apices in that species and from *T. schmidi* by the presence of prominent lateral lobes on the aedeagus of that species. Females for these congeneric species are unknown, however the female subgenital plate is similar to that of *T. formosana* (Okamoto), although the median notch in that species is deeper and the plate reaches beyond midlength of sternum 9 (Sivec et al. 1988). The eggs of the new species are the only known for the genus in which the chorion is coarsely pitted around both polar areas, but smooth over the equatorial zone.

Tyloperla karnataka sp. n.
(Figs. 21-30)

Material examined. Holotype ♂, **India**, Karnataka, Agumbe Ghats, 13° 29.452'N, 75° 04.221'W, 9 October 2004, Svenson, Cameron, Miller (USNM). Paratypes: Same data, 2♀ (BYUC). Same site but 11 October 2004, canopy light trap, G. Svenson, 1♂ (BYUC).

Adult habitus. General color pale yellow-brown patterned with darker brown pigment. Head pale brown but with darker markings lateral to and forward of median ocellus, anterolateral to posterior ocelli, on lappets and limited amounts between ocelli (Fig. 21); pronotal disk pale brown with darker markings; a slender pale longitudinal band lies parallel to, but does not touch the median suture. Wings pale, veins pale amber except C and Sc pale. Femora pale except narrow, dark distal ring; tibiae pale brown. Head with scattered dark hairs over much of surface.

Male. Forewing length 15.5 mm. Abdominal sterna without lobes, sensilla basiconica patches or hair brushes. Hemitergal process short, reaching far short of tergum 9, and basal callus poorly offset from process (Fig. 22). A pair of small sclerites covered with fine spines occur on membranous area of

tergum 10 between hemitergal processes; tergum 9 with a small mesal lobe covered by a large sensilla basiconica patch and tergum 8 with a smaller mesal sensilla basiconica patch (Fig. 22). Aedeagus without spiny lobes; tube and sac in lateral aspect curved gradually ventrad and bearing a broad subapical band of variably sized spines (Fig. 24); band open in a narrow, mid dorsal, longitudinal spineless strip; basal-most spines small, relatively sparse, forming a band which extends from mid-length of aedeagus along ventral margin to the apical third on the dorsal margin (Fig. 24); basal spine band grades abruptly into a similar sized median band of larger, more regularly grouped spines, which abruptly changes into a narrow band of fine, elongate spines. Apex of aedeagal sac membranous and dorsal margin of tube lightly sclerotized; basal envelope armed with very fine spinules in irregular rows.

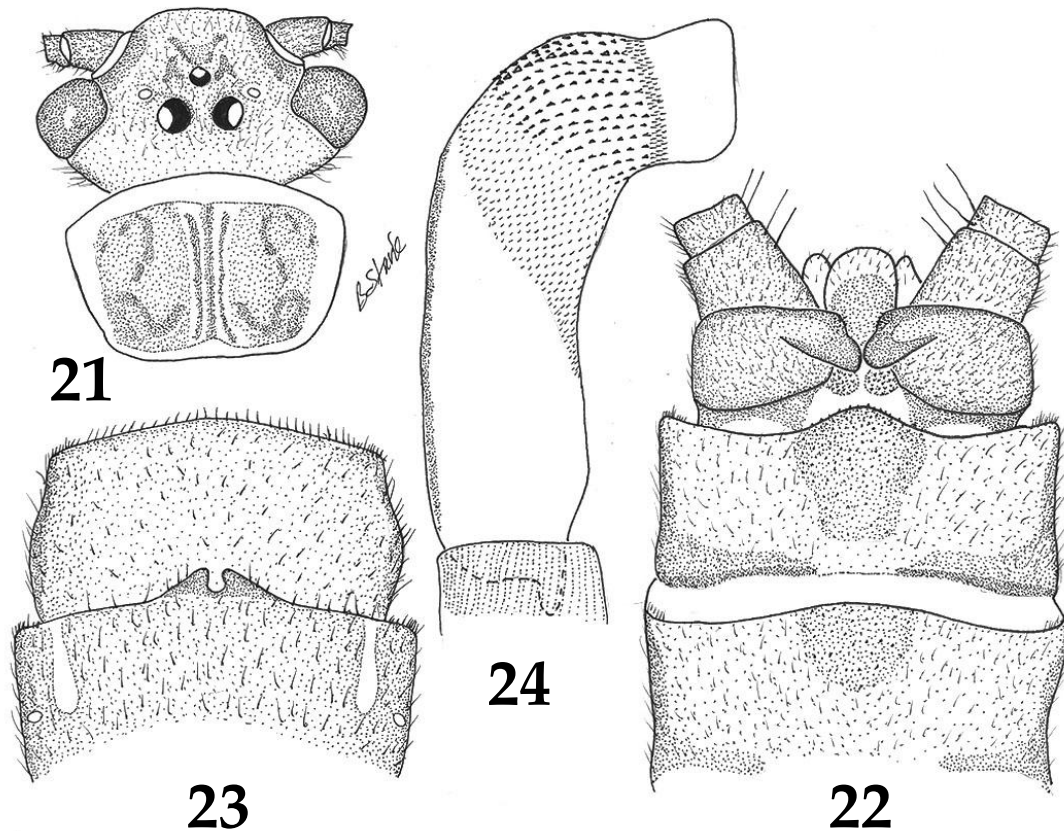
Female. Forewing length 19-21 mm. Subgenital plate on sternum 8 triangular in outline, barely projecting over base of sternum 9, and bearing a small U-shaped mesal notch; lobes of notch about as wide as notch and slightly darker than background color of sternum 8 (Fig. 23). Width of plate ca. 1/3 of sternal width.

Egg. Outline barrel-shaped. Length ca. 437 µm, equatorial width ca. 377 µm (Fig. 25). Smooth eclosion ring adjacent to unusually short lid; lid ca. 76 µm long. Collar short and wide, width ca. 164-186 µm (Figs. 25-27); rim flanged and irregularly and deeply incised (Figs. 26-27), ca. 14 irregular lobes in apical aspect (Fig. 27). Chorion covered throughout (except on smooth subequatorial eclosion ring) with mostly pentagonal and hexagonal follicle cell impressions; FCI cells located on equatorial side of eclosion ring have impunctate floors elevated above marginal grooves (Figs. 26, 29), those located on lid have corners of cells marked with shallow pits (Figs. 28, 30); aeropyles absent from FCIs. Micropyles with simple orifices located near opercular ring (Fig. 28). Eclosion ring ca. 24 µm wide in thicker areas, FCI cells ca. 27 µm across greatest width (Fig. 29).

Larva. Unknown.

Etymology. The species name, used as a noun in apposition, is based on the Indian state in which the holotype was collected.

Diagnosis. This species is similar to, but slightly larger and paler than *T. agumbe* (see description above), and the two species co-occur at the Agumbe Ghats site. Males of *T. karnataka* lack the distinctive



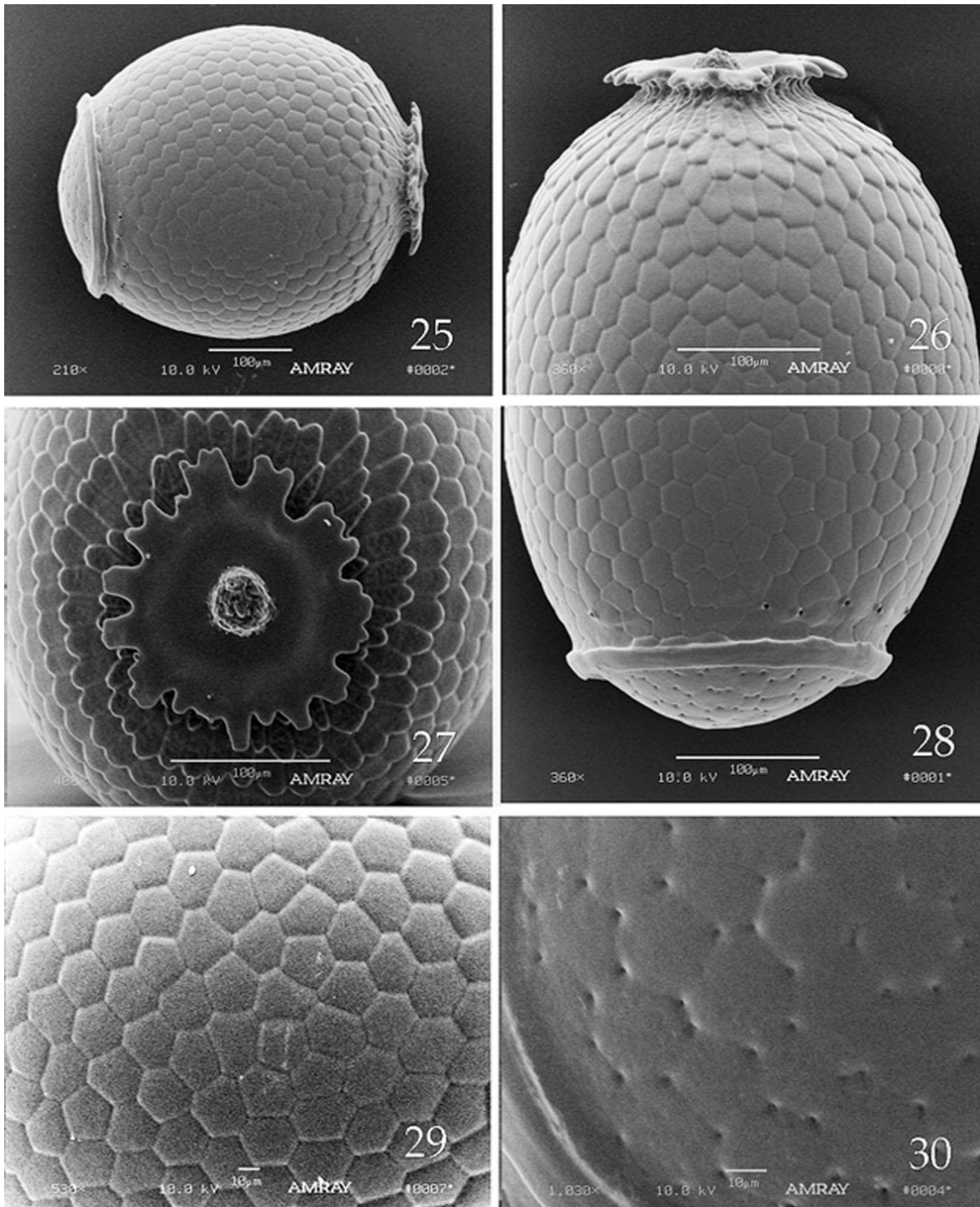
Figs. 21-24. *Tyloperla karnataka* structures. 21. Head and pronotum. 22. Male terminalia, dorsal. 23. Female terminalia, ventral. 24. Aedeagus, lateral.

lobe present on sternum 7 of *T. agumbe* (Fig. 3), and the aedeagus has a single broad band of variably sized spines and lacks a long laterally located seta (Fig. 24), whereas the aedeagus of *T. agumbe* bears two distinctly separated bands of similarly sized spines (Figs. 4-5) and bears on either side a single, long seta. The walls of the FCIs on most of the egg are slightly recessed as hexagonal grooves with the floors elevated and without aeropyles (Figs. 26, 28), but in *T. agumbe* the FCI corners are marked with small rounded tubercles and the floors have 5-7 aeropyles (Figs. 9-12). Female subgenital plates are similar and may overlap in basic morphology, but the present sample indicates the plate of *T. karnataka* is shorter and narrower at the base than the plate of

T. agumbe (Figs. 6, 23). It would also appear possible to distinguish adults of these species by comparing the pigment patterns of the head (Figs. 1, 21). The following keys are provided to assist in identifying *Tyloperla* specimens collected on the Indian subcontinent.

Key to *Tyloperla* Males from India

- 1 Hemitergal processes short and wide with rounded tips (Fig. 2) 2
- 1' Hemitergal processes elongate and slender with tapered tips (Fig. 14) 3
- 2 Abdominal sternum 7 bearing a small projecting lobe covered with sensilla basiconica (Fig. 3);



Figs. 25-30. *Tyloperla karnataka* egg structures. 25. Entire egg, lateral aspect. 26. Collar end. 27. Collar, apical aspect. 28. Equatorial zone, eclosion line and lid. 29. Chorionic detail, equatorial zone. 30. Chorionic detail, lid.

- aedeagus bearing an almost complete subapical spiny band and a second partial band located near midlength (Fig. 4) *agumbe*
- 2' Abdominal sterna without projecting lobes or sensilla basiconica; aedeagus bearing a single patch of variably sized spines (Fig. 24) *karnataka*
- 3 Tergum 9 with a broad median patch of sensilla basiconica; aedeagal sac bearing a pair of basolateral spiny lobes *schmidi*
- 3' Tergum 9 without sensilla basiconica patch (Fig. 14); aedeagal sac without basolateral spiny lobes (Fig. 15) *barog*

Key to *Tyloperla* Females from India

(*T. schmidi* unknown)

- 1 Subgenital plate without U-shaped notch, although a slight emargination may occur (Fig.

- 16); egg without eclosion line *barog*
- 1' Subgenital plate with a small median U-shaped notch on posterior margin (Fig. 6); egg with eclosion line (Fig. 25); equatorial chorionic zone bearing prominent hexagonal follicle cell impressions (Fig. 9) 2
- 2 Subgenital plate small, reaching less than 20% of sternum 9 length and comprising less than a third of the width of sternum 8 (Fig. 23); follicle cell impressions in equatorial zone without fine pores (Fig. 28); collar rim deeply and irregularly incised (Fig. 27) *karnataka*
- 2' Subgenital plate reaching at least midpoint of sternum 9 length and comprising about half the width of sternum 8 (Fig. 6); follicle cell impressions in equatorial zone with ca. 6 fine pores (Fig. 9); collar rim not deeply incised (Fig. 10) *agumbe*

Table 1. Annotated checklist of known *Tyloperla* species.

Species	Authors	Distribution
<i>T. attenuata</i>	(Wu & Claassen, 1934)	"Lu Ding Chiao", China
<i>T. agumbe</i>	sp. n.	Agumbe Ghats, Karnataka, India
<i>T. barog</i>	sp. n.	Barog, Himachal Pradesh, India
<i>T. bihypodroma</i>	Du, 2007	Folong, Shaanxi, China
<i>T. catcat</i>	Cao & Bae, 2007	Cat Cat, Sa Pa, Lao Cai, Vietnam
<i>T. courtneyi</i>	Stark & Sivec, 2005	Doi Inthanon, Chiang Mai, Thailand
<i>T. formosana</i>	(Okamoto, 1912)	Taiwan
<i>T. illiesi</i>	Stark & Sivec, 2005	Sapa, Lao Cai, Vietnam
<i>T. karnataka</i>	sp. n.	Agumbe Ghats, Karnataka, India
<i>T. khang</i>	Stark & Sivec, 2005 Cao & Bae, 2007	Gia Lai, An Khe, Vietnam Quang Nam and Thua Thien-Hue, Vietnam
<i>T. planistyla</i>	(Wu, 1973)	"Meng-sung", Yunnan, China
<i>T. sauteri</i>	(Navás, 1929)	Kosempo, Taiwan
<i>T. schmidi</i>	Stark & Sivec, 1991	Rupa, Assam, India
<i>T. sinensis</i>	Yang & Yang, 1993	Jinxiu, Guangxi, China
<i>T. trui</i>	Cao & Bae, 2007	Thua Thien-Hue, Vietnam; Ha Tinh, Vietnam; Quang Tri, Vietnam, Quang Binh, Vietnam

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