



RECORDS OF NEOPERLINI (PLECOPTERA: PERLIDAE) FROM BRUNEI DARUSSALAM AND SARAWAK, WITH DESCRIPTIONS OF NEW *PHANOPERLA* BANKS AND *NEOPERLA* NEEDHAM SPECIES

Bill P. Stark¹ and Andrew L. Sheldon²

¹Box 4045, Department of Biology, Mississippi College, Clinton, Mississippi, U.S.A. 39058
E-mail: stark@mc.edu

²Division of Biological Sciences, University of Montana, Missoula, Montana, U.S.A. 59812
E-mail: andylsheldon@comcast.net

ABSTRACT

Phanoperla astrospinata sp. n. and *P. belalong* sp. n. are proposed from specimens collected in Brunei Darussalam, and a provisional key for males of Bornean *Phanoperla* is presented. The first records for *Phanoperla pumilio* (Klapálek), *Neoperla divergens* Zwick, *N. parva* Banks, *N. sabah* Zwick, *N. securifera* Zwick, and *N. theobromae* Zwick from Brunei Darussalam are also given and a new species, *Neoperla grafei* sp. n., and a few records of *N. parva*, *N. rougemonti* Zwick and *Phanoperla anomala* x *bakeri* hybrids from Sarawak are included.

Keywords: Plecoptera, Perlidae, Neoperlini, New species, *Phanoperla*, *Neoperla*, Brunei Darussalam, Sarawak, Borneo

INTRODUCTION

The Bornean stonefly fauna includes five perlid genera, and at least 44 perlid species are currently known, principally from *Neoperla* Needham and *Phanoperla* Banks (Stark & Sivec 2007; Zwick, 1982, 1986a, b). This report, based on collections made in Brunei Darussalam by A.L. Sheldon and in Sarawak by U. Grafe in June and July, 2008, includes records of several previously described species and descriptions for two previously unrecognized *Phanoperla* from Brunei Darussalam, and one new *Neoperla* from Sarawak.

The principal collection site in Brunei Darussalam, Sungai Belalong, is a 15-30 m wide river draining an unlogged catchment in Ulu Temburong National Park. The stream at low flow is clear and consists of alternating pools and riffles or rapids, but is susceptible to afternoon spates which can

transform the river into a torrent with drifting logs, moving substrate and high turbidity. Cranbrook and Edwards (1994) provide additional details on the river and the surrounding terrestrial ecosystems. Most specimens were collected on the illuminated porch of the Kuala Belalong Field Studies Centre dining hall between sunset and 2200 hours.

Holotypes are deposited in the United States National Museum, Washington, D.C. (USNM); other specimens are deposited in the Slovenian Museum of Natural History, Ljubljana (PMSL) or the B.P. Stark collection, Clinton (BPS) as indicated in the text.

Genus *Neoperla* Needham

Zwick (1986a) recognized 30 Bornean *Neoperla* species and also made several informal designations based on unassociated female and larval material.

Subsequently Stark & Sivec (2007) described *N. darlingi* from West Kalimantan, and provided a few new records of *N. edmundsi* and *N. theobromae* from East Kalimantan.

Neoperla divergens Zwick

Neoperla divergens Zwick, 1986a:31. Holotype ♂ (Bernice P. Bishop Museum, Honolulu), Keningan, British North Borneo [Sabah]

Material examined. Brunei Darussalam: Temburong District, Sungai Belalong, Kuala Belalong Field Studies Centre, 04.54822°N, 115.15823°E, ALS B43-08, 11-16 July 2008, A.L. Sheldon, 1 ♂ (BPS).

Remarks. This species was previously known from a single male collected in "British North Borneo" in 1959.

Neoperla grafei sp. n. (Figs. 1-5)

Material examined. Holotype ♂ and 2 ♂ paratypes from Malaysia, Sarawak, Lanjak Entiman, 1.39°N, 112.16°E, 23 June 2008, U. Grafe (holotype USNM, paratypes BPS).

Adult habitus. General color pale yellow brown. Head pale except for obscure slightly darker region on frons and over ocelli (Fig. 1). Pronotum pale brown with scattered darker rugosities. Femora pale brown, tibiae similar but with dark brown band at knee. Wing membrane pale amber, veins brown.

Male. Forewing length 9.5 mm. Process of tergum 7 subtriangular with projecting sensilla basiconica around apex and on lateral margins (Fig. 2). Median sclerite of tergum 8 slightly rounded from lateral aspect and armed with a median row, and a few scattered sensilla basiconica. Tergum 9 with a pair of low humps armed with a sparse patch of ca. 7-8 sensilla basiconica; area between humps partially sclerotized and bearing a few smaller sensilla basiconica. Hemiterga typical, anterior finger lobes slender, straight and strongly narrowed at apex. Aedeagal tube slender and sclerotized except for a partial, near apical, membranous zone armed with strong apically directed spines (Figs. 3-5); apex of tube gradually curved ventrad. Aedeagal sac about as long as tube and armed along most of dorsal

margin with scattered strong spines; apex of sac with a patch of smaller, densely packed spines and ventral margin with a linear cluster of subapical spines.

Female. Unknown.

Larva. Unknown.

Etymology. The patronym honors Professor Ulmar Grafe, collector of the type series, for his gracious assistance in this study.

Diagnosis. *Neoperla grafei* is a member of the *N. parva* species group recognized by Zwick (1986a). It differs from other Bornean members of the complex (*N. edmundsi* Stark, *N. parva* Banks, *N. starki* Zwick) in details of aedeagal armature and tube shape. The new species is the only known member of the group with a strongly curved apex to the aedeagus, and it is also the only one to have the membranous spiny area of the tube set near the apex and extending as a partial ring across the dorsum; other species in the group have the spiny area distinctly separated into a pair of lateral patches located near midlength of the tube. This complex might be endemic to Borneo but Zwick (1986a) suggests *N. triangulata* Kawai, a Sri Lankan species, is a possible member of the group.

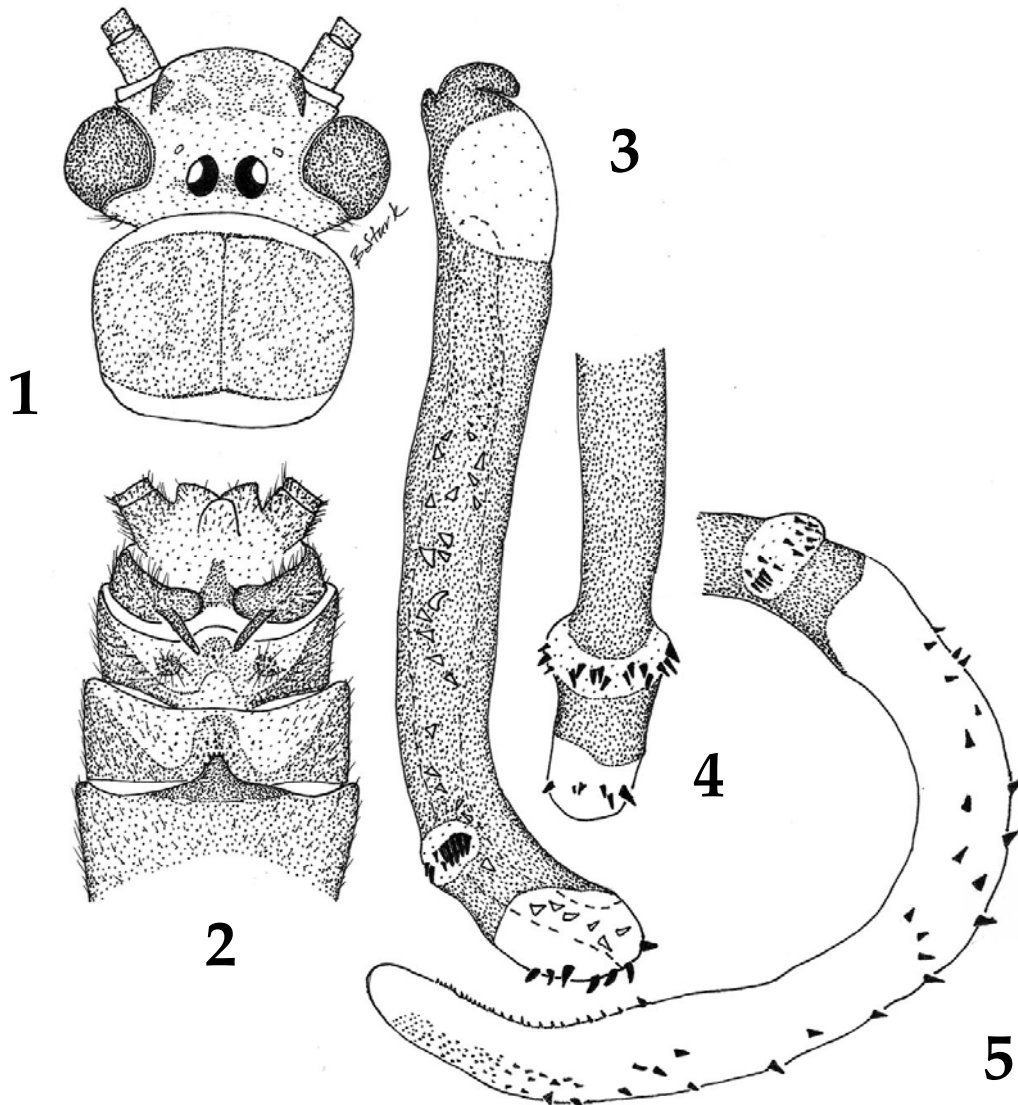
The holotype and paratypes of this species were collected with two males each of *N. parva* and *N. rougemonti*, and several females which do not appear to be any of these species.

Neoperla parva Banks

Neoperla parva Banks, 1939:446. Lectotype ♂ (Museum of Comparative Zoology, Harvard), Telang, Borneo, designation Zwick (1986a)

Neoperla parva: Zwick, 1986a:11

Material examined. Brunei Darussalam: Temburong District, Sungai Belalong, Kuala Belalong Field Studies Centre, 04.54822°N, 115.15823°E, ALS B36-08, 27 June 2008, A.L. Sheldon, 14 ♂, 44 ♀ (BPS, PMSL). Same site, ALS B20-08, 18 June 2008, A.L. Sheldon, 2 ♀ (BPS). Same site, ALS B21-08, 18 June 2008, A.L. Sheldon, 6 ♂, 4 ♀ (BPS). Same site, ALS B29-08, 23 June 2008, A.L. Sheldon, 3 ♂, 17 ♀ (BPS). Same site, ALS B39-08, 3 July 2008, A.L. Sheldon, 5 ♂ (BPS). Same site, ALS B44-08, 17 July 2008, A.L. Sheldon, 12 ♂, 5 ♀ (PMSL). Same site, ALS B45-08, 21-23 July 2008, A.L. Sheldon, 18 ♂ (BPS). Temburong District, Sungai Esu, ALS B 30-08, 28



Figs. 1-5. *Neoperla grafei*. 1. Head and pronotum, 2. Male terminalia, 3. Aedeagus, lateral aspect, 4. Aedeagus, dorsal aspect, internal sac armature not shown, 5. Aedeagal tube apex and everted sac, lateral aspect.

June 2008, A.L. Sheldon, 1 ♀ (BPS). Temburong District, Sungai Belalong, Sungai Esu mouth, 04.453509°N, 115.16212°E, ALS B 37-08, 4 July 2008, A.L. Sheldon, 2 ♀ (BPS). Malaysia: Sarawak: Lanjak Entiman, 1.39°N, 112.16°E, 23 June 2008, U. Grafe, 2 ♂ (BPS).

Remarks. This species was previously known from two Bornean sites and five total specimens (Zwick 1986a). These records include the first reports from

Brunei Darussalam.

***Neoperla rougemonti* Zwick**

Neoperla rougemonti Zwick, 1986a:7. Holotype ♂ (Zwick Collection, Schlitz), Skrang River, 2nd Division, Sarawak, Borneo

Material examined. Malaysia: Sarawak: Lanjak

Entiman, 1.39°N, 112.16°E, 23 June 2008, U. Grafe, 2 ♂ (BPS).

Remarks. This species was previously known from 11 specimens collected at two sites in Sarawak in 1932 and 1978.

Neoperla sabah Zwick
(Figs. 6-10)

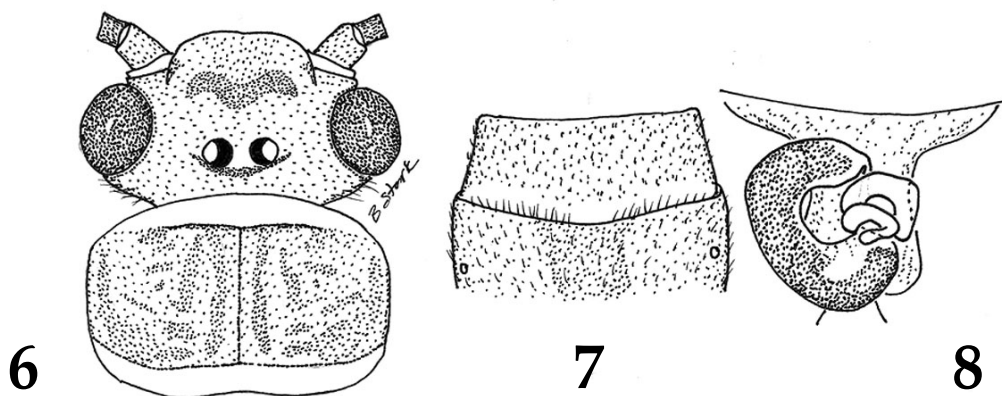
Neoperla sabah Zwick, 1986a:7. Holotype ♂ (Bernice P. Bishop Museum, Honolulu), North Borneo, 19 km N Kalabakan [Sabah]

Material examined. Brunei Darussalam: Temburong District, Sungai Belalong, Kuala Belalong Field

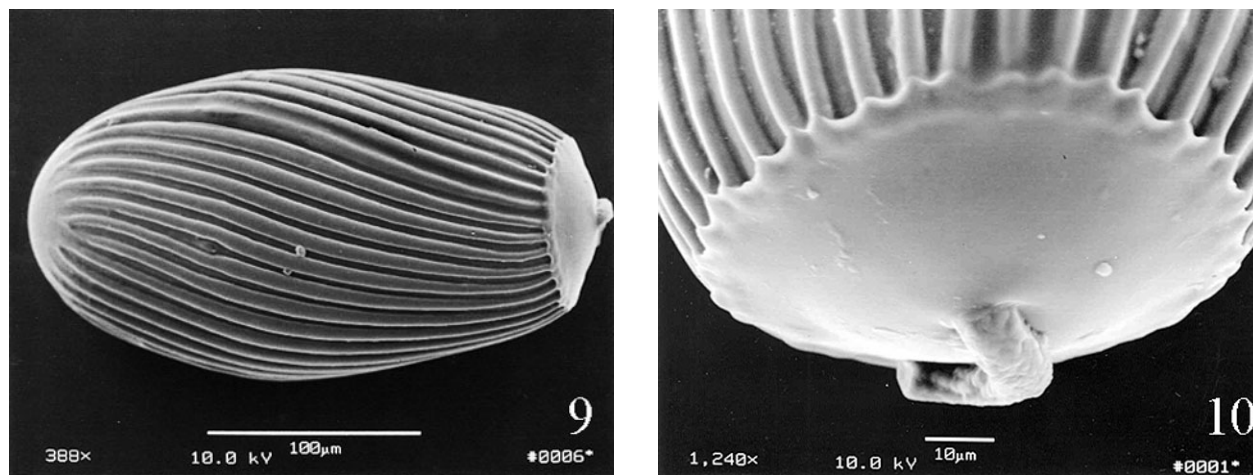
Studies Centre, 04.54822°N, 115.15823°E, ALSB36-08, A.L. Sheldon, 2 ♂ (BPS). Same site, ALS B29-08, 23 June 2008, A.L. Sheldon, 1 ♂, 1 ♀ (BPS).

Adult habitus. General color yellow brown. Head mostly pale but with brown arcuate mark behind ocelli and area between ocelli dark; M-line area and anteromedian area of frons slightly darker than background pigment (Fig. 6). Basal antennal segments pale brown, flagellum darker. Femora pale, tibiae darker; wing membrane pale amber, veins brown.

Female. Forewing length 10.5 mm. Posterior margin of sternum 8 unmodified (Fig. 7). Receptacular stalk C-shaped and almost completely armed internally with closely packed brown scales (Fig. 8); vagina slightly constricted near midlength.



Figs. 6-8. *Neoperla sabah*. 6. Head and pronotum, 7. Female abdominal sterna 8-9, 8. Vagina.



Figs. 9-10. *Neoperla sabah* egg structures. 9. Entire egg, lateral aspect, 10. Anchor pole.

Egg. Length from tip of lid to rim of anchor pole, ca. 225.0 µm; diameter, ca. 147.5 µm. Most of egg body covered by narrow, spiral striae (ca. 18 in lateral view) separated by narrow, punctate sulci (Fig. 9). Base of anchor arises from center of convex, impunctate plate covering anchor pole; margins of plate scalloped with small projecting teeth over base of each striation (Fig.10). Lid punctate with tiny aeropyles over entire surface.

Remarks. Zwick (1986a) described this species from five males taken at two localities in Sabah. These are the first specimens taken in Brunei Darussalam. The female association is based on a common pattern of brown pigment behind the ocelli. Eggs are similar to those of *N. rougemonti* (Zwick 1986a) but have spiral striae rather than straight ones.

Neoperla securifera Zwick

Neoperla securifera Zwick, 1986a:28. Holotype ♂ (Rijksmuseum van Natuurlijke Histoire, Leiden), Midden-Oost Expedition, between Samarinda and Long Petak, Borneo

Material examined. Brunei Darussalam: Temburong District, Sungai Belalong, Kuala Belalong Field Studies Centre, 04.54822°N, 115.15823°E, ALS B11-08, 11 June 2008, A.L. Sheldon, 1 ♂ (BPS).

Remarks. Zwick (1986a) found this to be a variable species based on a few males collected at several Bornean sites. The aedeagus of the male listed above is very similar to Fig. 56 in Zwick (1986a) but the median process of tergum 7 more closely resembles that of *N. multilobata* Zwick. This is the first record from Brunei Darussalam.

Neoperla theobromae Zwick

Neoperla theobromae Zwick, 1986a:9. Holotype ♂ (Bernice P. Bishop Museum, Honolulu), Tawau, Quoin Hill, Cocoa Research Station, North Borneo [Sabah]
Neoperla theobromae: Stark & Sivec, 2007:56

Material examined. Brunei Darussalam: Temburong District, Sungai Belalong, Kuala Belalong Field Studies Centre, 04.54822°N, 115.15823°E, ALS B36-08, 27 June 2008, A.L. Sheldon, 1 ♂ (BPS). Same site, ALS B45-08, 21-23 July 2008, A.L. Sheldon, 2 ♂ (BPS). Same site, ALS B21-08, 18 June 2008, A.L. Sheldon, 1

♂ (BPS).

Remarks. This species was previously known from three sites in Sabah and one each in East Kalimantan and Sarawak (Stark & Sivec 2007; Zwick 1986a). This is the first report from Brunei Darussalam.

Neoperla sp. BoM

Neoperla spec. BoM Zwick, 1986a:50. Female and egg description

Neoperla sp. BoM Stark & Sivec, 2007:57. SEM of egg

Material examined. Brunei Darussalam: Temburong District, Sungai Temburong, park landing, 14 June 2008, ALS B 16-08, A.L. Sheldon, 1 ♀ (BPS).

Remarks. This informally designated female, easily recognized from the distinctive egg, is now known from localities in Sarawak, East Kalimantan and Brunei Darussalam (Stark & Sivec 2007; Zwick 1986a). Unfortunately, Zwick (1986a) designated two different Bornean species with the BoM code (one on page 17, Figs. 28-30) and this species on page 50 (Figs. 114-115). Although this species has subsequently been collected twice, it has yet to be associated with a male.

Genus *Phanoperla* Banks

Zwick (1982, 1986b) gave formal recognition to seven Bornean *Phanoperla* species and left one potentially distinct form (*P.* species cf *maculata*) without resolution. Stark & Sivec (2007) recognized two additional species (*P. flabellare*, *P. tuberosa*) and also gave new records for *P. flaveola* (Klapálek) and *P. pumilio* (Klapálek) from East Kalimantan. The following provisional key for males will assist in recognizing the 11 nominal Bornean species.

Provisional Key to Males of Bornean *Phanoperla*

- 1 Small anterior ocellus present; largest aedeagal armature consists of a subapical ring of black hooks, incomplete on venter *anomala*
- 1' Anterior ocellus absent; aedeagal armature variable but not as above 2
- 2 Median sensilla basiconica patch of tergum 9 well developed (Fig. 13); largest aedeagal armature consists of a pair of lateral fan-like groups of 3-7 black

- spines (Fig. 14) 3
- 2' Median sensilla basiconica patch of tergum 9 absent, or reduced to a few scattered pegs (Fig. 11); largest aedeagal armature variable but not as above (Fig. 12) 5
- 3 Median sensilla basiconica patch of tergum 9 discretely separated from lateral patches; black scale spines on aedeagal apex cover ventrolateral surface but dorsum bare *flabellare*
- 3' Median sensilla basiconica patch of tergum 9 loosely united with lateral patches (Fig. 13); black scale spines on aedeagal apex cover entire circumference (Fig. 14) 4
- 4 Bases of hemitergal processes about as wide as basal cushions; a small spiny mound located dorsad to lateral fan clusters of large spines (Fig. 14) *belalong*
- 4' Bases of hemitergal processes narrower than basal cushions; spiny lobes absent from area of fan clusters of large spines *tuberosa*
- 5 Aedeagal armature includes a single, complete, subapical ring of large hooks *bakeri*
- 5' Aedeagal armature with two rows or clusters of large hooks (Fig. 12) 6
- 6 Aedeagal armature with two close-set, incomplete subapical rows 7
- 6' Aedeagal armature with rows or clusters widely separated (Fig. 12) 8
- 7 Subapical rows of large hooks almost complete; a nose shaped subapical aedeagal lobe present; wing veins usually bordered with brown pigment *nervosa*
- 7' Subapical rows of large hooks widely separated dorsally; nose shaped subapical lobe absent; wing veins without brown pigment borders *incompleta*
- 8 Apical aedeagal hooks form a complete ring; subapical hooks set on a pair of low membranous, dorsolateral mounds *pumilio*
- 8' Apical hooks not as above 9
- 9 Apical aedeagal hooks form an incomplete row; subapical hooks form an incomplete, sometimes double ventrolateral row *maculata*
- 9' Aedeagal hooks not as above 10
- 10 Ventrolateral patches of large spines asterisk-like (Fig. 12) *astrospinata*
- 10' Ventrolateral patches of large spines arranged in a

short row *flaveola*

***Phanoperla anomala* X *bakeri* hybrid**

Material examined. Malaysia: Sarawak, Lanjak Entiman, 1.39°N, 112.16°E, 23 June 2008, U. Grafe, 1 ♂ (BPS).

Remarks. The aedeagus of this specimen is very similar to the illustration (Fig. 15) in Zwick (1986b) which shows a "*Phanoperla bakeri* x *anomala* hybrid". Larger samples are needed in order to evaluate this hypothesis.

***Phanoperla astrospinata* sp. n.**

(Figs. 11-12)

Material examined. Holotype ♂ from Brunei Darussalam, Temburong District, Sungai Belalong, Kuala Belalong Field Studies Centre, 04.54822°N, 115.15823°E, ALS B43-08, 11-16 July 2008, A.L. Sheldon (USNM).

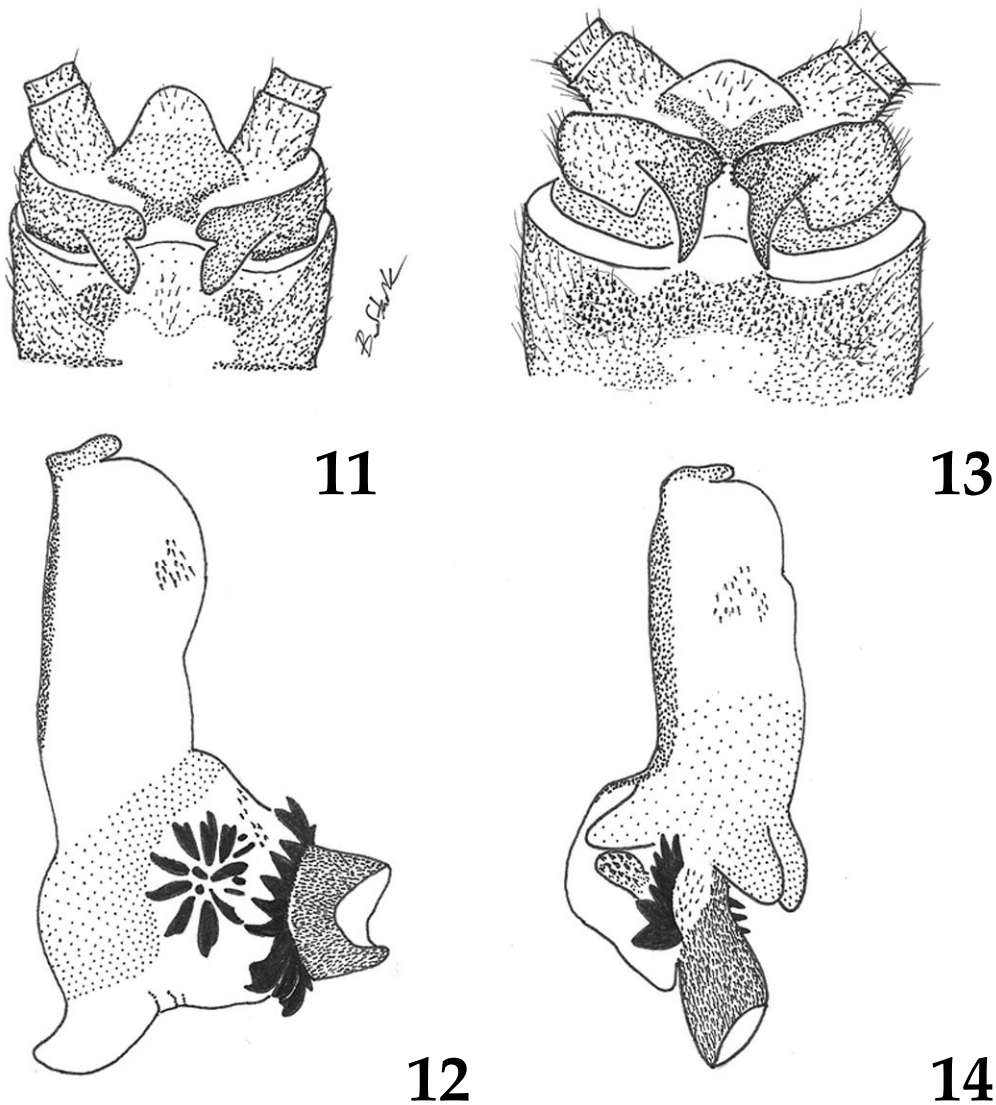
Adult habitus. Body color pale white in alcohol. Head without distinctive pigment pattern; ocelli almost touching. Antennal bases pale but flagellum beyond basal segments, dark brown. Pronotum with pale brown rugosities and darker marginal and median sutures. Tibiae about as wide as femora and slightly darker. Wings pale with pale yellow veins.

Male. Forewing length 7.5 mm. Tergum 8 unmodified, tergum 9 with a pair of lateral sensilla basiconica patches and a median patch of fine, short setae (Fig. 11). Hemiterga short and relatively wide with rounded tips in dorsal aspect; apices hooked downward in lateral aspect and bearing a few enlarged sensilla basiconica; notch separating basal callus narrow and deep. Aedeagal tube short and plump with a few fine setal spines on bulb; apex swollen and heavily armed with spines (Fig. 12); Largest and most prominent armature consists of a subapical ring of ca. 22 black spines and a pair of star-like, lateral clusters. Additional small, triangular spines occur over a broad zone, proximal to star clusters and on apical zone distal to spine ring. Frontal area below spine ring, bare and produced into a membranous nose-like process. Dorsal sclerite slender and poorly sclerotized.

Female. Unknown.

Larva. Unknown.

Etymology. The species name refers to the star pattern of large spines on the aedeagus sac.



Figs. 11-14. *Phanoperla astrospinata* (11-12) and *P. belalong* (13-14). 11. Male terminalia, 12. Aedeagus, lateral aspect, 13. Male terminalia, 14. Aedeagus, lateral aspect.

Diagnosis. The aedeagus and external genitalia of this species is generally similar to that of *P. flaveola* (Zwick 1982) and it appears to be a member of that group. These structures are also generally similar to, or perhaps the same as, *Phanoperla* cf. *maculata* of Zwick (1986b). That designation was based on a pair of Bornean specimens from the 1932 Oxford University Expedition studied by Zwick (1986b), but whose status was not formally defined. The present specimen has the same general pattern of spines on

the aedeagus, however there are fewer large lateral spines and they are arranged in a more distinct star pattern than in Zwick's specimens. In addition, fine triangular spines are shown by Zwick (1986b) along the frontal zone, and no nose shaped process is shown for his specimens. The new species is also distinguished from *P. flaveola* by the star cluster of lateral aedeagal spines. The lateral grouping of that species forms a linear group of 5-6 large spines, and in addition, the dorsal aedeagal sclerite is much

larger for *P. flaveola* than for the new species.

Phanoperla belalong sp. n.

(Figs. 13-14)

Material examined. Holotype ♂ from Brunei Darussalam, Temburong District, Sungai Belalong, Kuala Belalong Field Studies Centre, 04.54822°N, 115.15823°E, ALS B39-08, 3 July 2008, A.L. Sheldon (USNM). Paratypes. Same site but ALS B24-08, 18 June 2008, A.L. Sheldon, 1 ♂ (BPS). Same site but ALS B36-08, 27 June 2008, A.L. Sheldon, 1 ♂ (BPS).

Adult habitus. Body color pale yellow brown. Head yellow brown without pattern; ocelli almost touch. Basal 4-5 antennal segments pale, rest of flagellum brown. Pronotum pale with darker rugosities and dark brown median and marginal sutures. Femora pale, tibiae brown. Wings pale, veins amber.

Male. Forewing length 7.5 mm. Tergum 8 unmodified, tergum 9 with lateral and mesal sensilla basiconica patches united, or almost so (Fig. 13). Hemiterga with attenuated tips; basal callus offset from apical section of hemiterga by broad, shallow emargination. Aedeagal tube short and plump with a few fine setal spines on bulb; apex of tube bearing a pair of ventromedian lobes and a pair of dorsolateral lobes (Fig. 14); apical half of tube, including lobes armed with fine triangular spines. Aedeagal sac bearing lateral groups of 6-7 large black spines in fan shaped clusters on either side of a cylindrical lobe densely armed with black, scale-like spines; dorsad to large fan shaped clusters, a small membranous lobe, armed with brown, triangular spines occurs on each side of sac. Dorsal sclerite spear shaped but apex curved dorsad over base of sac.

Female. Unknown.

Larva. Unknown.

Etymology. The species name, used as a noun in apposition, is based on the type locality of Sungai Belalong and the Kuala Belalong Field Studies Centre.

Diagnosis. The aedeagal features of this species are similar to both *P. flabellare* Stark & Sivec and to *P. anomala* (Banks) (Stark & Sivec 2007; Zwick 1982). It differs from the former in bearing two pairs of prominent, membranous, spine-covered lobes ventroapically and dorsolaterally on the tube. In addition, a small spiny lobe occurs dorsad to the

large fan shaped clusters of spines on the sac. The latter species shares the ventroapical spiny lobes on the aedeagal tube but the sac is armed with an almost complete ring of large black spines.

Phanoperla pumilio (Klapálek)

Neoperla pumilio Klapálek, 1921:320. Lectotype ♂ (National Museum, Prague), Sebroang, Borneo, designated by Zwick, 1982

Phanoperla pumilio: Zwick, 1982:111

Phanoperla pumilio: Stark & Sivec, 2007:59

Material examined. Brunei Darussalam, Temburong District, Sungai Belalong, Kuala Belalong Field Studies Centre, 04.54822°N, 115.15823°E, 21 July 2008, ALS B45-08, A.L. Sheldon, 1 ♂ (BPS). Same site, 27 June 2008, ALS B36-08, A.L. Sheldon, 1 ♂ (BPS).

Remarks. The surviving type series of this species includes a male and two females from Sebroang, Borneo (Zwick 1982) and a second male and five female specimens were reported by Stark & Sivec (2007) from East Kalimantan. These males represent the first record of the species from Brunei Darussalam.

ACKNOWLEDGEMENTS

Field research was conducted at the Kuala Belalong Field Studies Centre of Universiti Brunei Darussalam under permit UBD/KBFSC/R/2 and specimens were forwarded to Mississippi College under export permit JMB/209/68/2. We thank Professor U. Grafe, Universiti Brunei Darussalam, for assistance in obtaining these specimens and for information about collecting localities, and we also thank Rodzay for suggesting the porch as a collecting source for specimens and O. Konopik for his contribution of specimens.

REFERENCES

- Banks, N. 1939. New genera and species of neuropteroid insects. *Bulletin of the Museum of Comparative Zoology*, 85:439-504.
- Cranbrook, Earl of & D.S. Edwards. 1994. A tropical rainforest: The nature of biodiversity in Borneo at Belalong, Brunei. The Royal Geographical Society, London, UK and Sun Tree Publishing, Singapore. 389 pp.

Stark B.P. & A.L. Sheldon. 2009. Records of Neoperlini (Plecoptera: Perlidae) from Brunei Darussalam and Sarawak, with descriptions of new *Phanoperla* Banks and *Neoperla* Needham species. *Illiesia*, 5(2):11-19. Available online: <http://www2.pms-lj.si/illiesia/papers/Illiesia05-02.pdf>

Klapálek, F. 1921. Plécoptères nouveaux. Annales de la Société Entomologique de Belgique, 61:57-67, 146-150, 320-327.

Stark, B.P. & I. Sivec. 2007. Studies of Indonesian Perlidae (Plecoptera), with descriptions of three new species. *Illiesia*, 3:53-64.

Zwick, P. 1982. A revision of the Oriental stonefly genus *Phanoperla* (Plecoptera: Perlidae). *Systematic Entomology*, 7:87-126.

Zwick, P. 1986a. The Bornean species of the stonefly genus *Neoperla* (Plecoptera: Perlidae). *Aquatic Insects*, 8:1-53.

Zwick, P. 1986b. Contribution to the knowledge of *Phanoperla* Banks, 1938 (Plecoptera: Perlidae). *Mitteilungen der Schweizerischen Entomologischen Gesellschaft*, 59:151-158.

Received 29 January 2009, Accepted 2 February 2009, Published 5 February 2009