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Research article

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A strikingly coloured new giant millipede from Vietnam has copycat in Borneo (Diplopoda, Spirostreptida, Harpagophoridae)

Piyatida PIMVICHAI^{1,*}, Nesrine AKKARI², Irina SEMENYUK³,
Jerôme CONSTANT⁴ & Henrik ENGHOFF⁵

¹Department of Biology, Faculty of Science, Mahasarakham University,
Mahasarakham 44150, Thailand.

²Naturhistorisches Museum Wien, Burgring 7, 1010 Vienna, Austria.

³A.N. Severtsov Institute for Problems of Ecology and Evolution, Russian Academy of Sciences,
Leninsky pr. 33, Moscow 119071, Russia.

³Joint Russian-Vietnamese Tropical Center, Street 3 Thang 2, 3, Q10, Ho Chi Minh City, Vietnam.

⁴Royal Belgian Institute of Natural Sciences, O.D. Taxonomy & Phylogeny – Entomology,
Vautier street 29, B-1000 Brussels, Belgium.

⁵Natural History Museum of Denmark, University of Copenhagen, Universitetsparken 15,
DK-2100 Copenhagen Ø, Denmark.

*Corresponding author: piyatida.p@msu.ac.th

²Email: nesrine.akkari@nhm-wien.ac.at

³Email: free-cat@bk.ru

⁴Email: jconstant@naturalsciences.be

⁵Email: henghoff@snm.ku.dk

¹[urn:lsid:zoobank.org:author:4D882A89-E0C1-4F78-93E7-FA1B5A2650F2](https://zoobank.org/author/4D882A89-E0C1-4F78-93E7-FA1B5A2650F2)

²[urn:lsid:zoobank.org:author:DC6FB247-5F4F-4700-9DB6-6588A99370A0](https://zoobank.org/author/DC6FB247-5F4F-4700-9DB6-6588A99370A0)

³[urn:lsid:zoobank.org:author:5926D032-BDC8-42D1-B3FF-087CDC6AA5D7](https://zoobank.org/author/5926D032-BDC8-42D1-B3FF-087CDC6AA5D7)

⁴[urn:lsid:zoobank.org:author:6E6072A1-9415-4C8D-8E60-2504444DB290](https://zoobank.org/author/6E6072A1-9415-4C8D-8E60-2504444DB290)

⁵[urn:lsid:zoobank.org:author:FB09A817-000D-43C3-BCC4-2BC1E5373635](https://zoobank.org/author/FB09A817-000D-43C3-BCC4-2BC1E5373635)

Abstract. A new giant species of the subfamily Rhynchoproctinae with strikingly bi-coloured, red-yellow legs contrasting with a black body is described: *Alienostreptus bicoloripes* sp. nov. from Vietnam. The new species is assigned to the genus *Alienostreptus* Pimvichai, Enghoff & Panha, 2010 hitherto comprising one species, *A. alienus* (Attems, 1936), and differing from other rhynchoproctine genera by having the femoral spine duplicated. Species of this genus share three synapomorphic characters of the subfamily, viz (1) anterior coxal fold forms deep concavity in posterior view, (2) posterior coxal fold very low, and (3) posterior coxal fold with mesal flap. A superficially very similar colourful species from Borneo, also with bi-coloured legs but clearly not belonging to *Alienostreptus* due to the position of ventral soft pads on male legs, is documented based on photographs.

Keywords. New species, Southeast Asia, taxonomy.

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Introduction

Most of the large to gigantic millipede species in Southeast Asia belong to the family Harpagophoridae Attems, 1909. Based mainly on gonopodal characters, Jeekel (2006) divided the family into three subfamilies, viz, Harpagophorinae Attems, 1909, Adiphorostreptinae Hoffman, 1977 and Rhynchoproctinae Demange, 1961. The subfamily Rhynchoproctinae is a monophyletic group sharing three synapomorphic gonopodal characters: anterior coxal fold (*ac*) forming a deep concavity in posterior view; posterior coxal fold (*pc*) very low; posterior coxal fold mesally with a ‘flap-like’ process (Pimvichai *et al.* 2010). The subfamily currently includes 35 species in 14 genera (Zhang *et al.* 1997; Jeekel 2006; Pimvichai *et al.* 2010). The genus *Alienostreptus* Pimvichai, Enghoff & Panha, 2010 differs from other rhynchoproctine genera by having duplicated femoral spines.

The majority of species of the subfamily Rhynchoproctinae is distributed in southern China, Myanmar, Thailand, Laos, Cambodia and Vietnam. A few species are distributed in Borneo, Malacca Peninsula, Sumatra, Sunda Islands and as far south as Lombok.

Until now, only two species in two genera of Rhynchoproctinae have been reported from Vietnam, viz, *Alienostreptus alienus* (Attems, 1936) and *Uriunceustreptus uniserialis* (Attems, 1938). Based on new material from Vietnam, we describe a new colourful giant millipede, the second species of the genus *Alienostreptus*. The present study provides a new diagnosis of the genus in order to include the new species.

Several photographs of a superficially very similar species from Borneo exist, but no specimen has been available. The Bornean species is strikingly similar to the new species from Vietnam. However, the colour of the legs is slightly different, and the position of the ventral soft pads on male legs is also different. We, therefore, regard the Bornean specimens as belonging to a genus different from *Alienostreptus*.

Material and Methods

Specimens were examined from the following collections:

NHMW = Naturhistorisches Museum Wien, Vienna, Austria
RBINS = Royal Belgian Institute of Natural Sciences, Brussels, Belgium
ZMUM = Zoological Museum, State University of Moscow, Russia

The morphological terminology follows previously published papers (Pimvichai *et al.* 2009, 2010). Living specimens were photographed with a digital camera.

Measurements and photographs were made with a Nikon DS-Fi2 camera mounted on a Nikon SMZ25 stereo microscope, using the NIS-Elements Microscope Imaging Software with an Extended Depth of Focus (EDF) and edited in Adobe Photoshop CS6.

Gonopods drawings were performed with pencil and then black liners using a Olympus SZ-61 stereo microscope, sketches were scanned with a CanoScan Lide 60 scanner and then edited with Corel Photo-Paint X5 software. Figure plates were assembled in Adobe Photoshop CS6.

Gonopod terminology

We use the following terminology for the gonopod structure of the genus *Alienostreptus* (terms not in Pimvichai *et al.* 2010 in **bold**):

- as* = additional spine: an additional spine on the telopodite, different from femoral spine (*fe*) and tibial spine (*ti*)
- ac* = anterior coxal fold: the main part of the gonopod as seen in anterior view. Confusingly called *posterior* coxal fold by Demange (1961) and Hoffman (1975)
- ca* = canopy of anterior coxal fold: the canopy-like apical part of the anterior coxal fold in some species
- fe* = femoral spine: a spine originating slightly distal to the point where the telopodite is flexed ('knee') or where the telopodite emerges from the coxa
- fl* = flap: a mesal, lamellar process of posterior coxal fold (*pc*)
- lr*** = **lateralmost ridge**: lateralmost ridge of posterior coxal fold (*pc*)
- mr*** = **mesal ridge**: mesal ridge of posterior coxal fold (*pc*)
- pc* = posterior coxal fold: the main part of the gonopod as seen in posterior view, much shorter than anterior coxal fold (*ac*)
- px* = paracoxite: the basal, lateral part of the posterior coxal fold
- sp* = setalike spines: apical processes on the solenomere, slender, pale, soft
- ti* = tibial spine: a long spine on the telopodite, originating distal to the femoral spine, at the basis of the apical part of the telopodite
- tp*** = **triangular process**: a pointed triangular process of lateralmost ridge (*lr*) of posterior coxal fold (*pc*)
- tr* = transverse ridges: transverse ridges across the outer surface of the solenomere

Apical part = the distalmost part of the telopodite

Results

Taxonomy

Class Diplopoda Blainville-Gervais, 1844
Order Spirostreptida Brandt, 1833
Family Harpagophoridae Attems, 1909
Subfamily Rhynchoproctinae Demange, 1961

Genus *Alienostreptus* Pimvichai, Enghoff & Panha, 2010

Alienostreptus Pimvichai *et al.*, 2010: 58.

Type species

Thyropygus alienus Attems, 1936, by original designation. This until now monotypic genus was erected by Pimvichai *et al.* (2010) who agreed with Jeekel (2006) that *Thyropygus alienus* is not congeneric with *Thyropygus mundus* Attems, 1936, type species of *Cercostreptus* Demange, 1961, a genus originally, but invalidly, created as a new subgenus of *Anurostreptus* Attems, 1914 by Attems (1942).

In the morphology-based phylogeny of Rhynchoproctinae by Pimvichai *et al.* (2010), *Alienostreptus* comes out in the middle of a paraphyletic sequence of one-genus branches, between *Balustreptus* Hoffman, 1980, and *Winklerostreptus* Demange, 1969. Phenetically, *Alienostreptus* is most similar to *Balustreptus*, sharing a series of transverse ridges across the apical part of the telopodite, presence of more than one spine on gonopod telopodites, presence of tarsal pads covering the entire ventral surface

only on tibia of walking legs, and an unmodified collum. From *Balustreptus*, *Alienostreptus* differs, i.e., by having two ‘femoral’ spines on the gonopods as well as having the apical part of the telopodite broadly expanded.

Pimvichai *et al.* (2010) diagnosed the genus *Alienostreptus* based on one species, viz, *Alienostreptus alienus* (Attems, 1936). Here, we revise the genus diagnosis to accommodate the new species (characters changed from Pimvichai *et al.* 2010 in **bold**):

A genus of Rhynchoproctinae. Collum narrowed laterally, ends rounded–truncate, with strong anterolateral marginal groove and ridge; stipes of mandibles with a ventral abruptly narrowed swollen lobe; coxae of the seventh pair of legs unmodified; ventral soft pads only on tibiae on all legs except first two pairs; **epiproct with a projection**; hypoproct completely fused with epiproct. Gonopod sternum (*st*) absent; flap (*fl*) tongue-shaped, thin, projecting caudad from mesal margin of coxa; **femoral spine long, duplicated (*fe*)**; **apical part of telopodite broadly expanded**, with several strong transverse ridges (*tr*) across outer surface, apically with a row of pale spines (*sp*).

Alienostreptus alienus (Attems, 1936)

Figs 1, 8

Thyropygus alienus Attems, 1936: 260.

Anurostreptus (*Cercostreptus*) *alienus* – Attems 1938: 95.

“*Cercostreptus*” *alienus* – Jeekel 2006: 41.

Alienostreptus alienus – Pimvichai *et al.* 2010: 59, fig. 5.

Diagnosis

Differs from *A. bicoloripes* sp. nov., the only known congener, as specified below in the diagnosis of the new species.

Material studied

VIETNAM • 1 ♂, syntype of *Thyropygus alienus* Attems, 1936, dissected, broken into three parts, extra vial with gonopods, of which one dissected and missing telopodite (NHMW 2556), one leg and one telopodite (NHMW 2604); “Dran Langbian Prov., S. Annam Calcutta M. 1934, leg. C. Boden Kloss, iii–v.1918.”; NHMW 2556, NHMW 2604.

Notes

See Attems (1936) and Pimvichai *et al.* (2010) for the full description of this species. The gonopods of *A. alienus* were fully illustrated (Pimvichai *et al.* 2010: fig. 5). Here, we document the syntype of *A. alienus* housed in NHMW, also for comparison with the new species (Fig. 1).

Alienostreptus alienus is known from the type locality in Vietnam, South Annam, D’Ran, 3000 feet, Lam Dong Province, and from Vietnam Lam Dong Province, Klong Klanh ranger station, Bidoup-Nui Ba National Park (Pimvichai *et al.* 2010; Fig. 8). (Locality names updated to presently valid forms.)



Fig. 1. *Alienostreptus alienus* (Attems, 1936), syntype (NHMW 2556). **A.** Head and anterior body rings, lateral view. **B.** Ultimate body rings, lateral view. **C.** Head and first body rings, ventral view. **D.** Right gonopod coxa, apical view. **E.** Right gonopod (distal part of telopodite broken), posterior view.

Alienostreptus bicoloripes sp. nov.

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Figs. 2–6, 8

Diagnosis

Differs from the only other species in the genus, *A. alienus*, by:

- larger size
- straight preanal process (epiproct)
- tip of anterior coxal fold (*ac*) forming a flattened, sickle-shaped lamella with serrate margins
- canopy of anterior coxal fold (*ca*) with a broad, rounded lobe (in *A. alienus* with serrate margins)
- apical part of telopodite forming a single broadly expanded sheet, in *A. alienus* ending in two branches
- tibial spine much shorter than in *A. alienus*

Etymology

The species epithet refers to the strikingly bi-coloured legs.

Type material

Holotype

VIETNAM • ♂, Gia Lai Prov., Kon Chu Rang Nature Reserve; 14°28'28" N, 108°32'27" E; 500–1200 m a.s.l.; 13–20 Jul. 2018; J. Constant, J. Bresseel and X. Vermeersch leg.; GTI project; RBINS I.G.33.769/001.

Paratypes

VIETNAM • 1 ♂, 2 ♀♀; same collection data as for holotype; RBINS I.G.33.769/002, I.G.33.769/003, I.G.33.769/004 • 3 ♂♂, 1 ♀, 1 juvenile; Gia Lai Prov., Kon Chu Rang Nature Reserve; 14°27–31' N, 108°32–36' E.; 950–1050 m a.s.l.; 23 May–2 Jun. 2016 and 26 Mar.–6 Apr. 2018; I. Semenyuk leg.; ZMUM.

Description

Males

Adult males (the holotype and paratypes) with 58–60 podous rings, no apodous rings. Length 16–17 cm, width 10.3–10.5 mm. Overall colour of living specimen (Fig. 2A–C) including antennae, prozona, metazona, epiproct, paraprocts and hypoproct dark brown (almost black). Legs and antennae bi-coloured, antennomeres 1–4, legs from coxae to postfemora brownish orange; antennomeres 5–7, tibiae and tarsi of legs yellow.

HEAD. Head capsule smooth, no supralabral setae; eyes moderate in size, ommatidia in 7 horizontal rows, eye of one male with $9 + 10 + 9 + 8 + 6 + 5 + 3 = 50$ ommatidia.

ANTENNAE. Almost reaching back to body ring 3, length of antennomeres: $2 > 3 > 4 > 5 > 1 > 6 > 7$.

MANDIBLE. Stipes with disto-posterior lobe, ventral side of lobe thickened, with pale, soft area.



Fig. 2. *Alienostreptus bicoloripes* sp. nov. A–C. Living females (from Kon Chu Rang Nature Reserve, Gia Lai Province), paratypes (RBINS, ZMUM). D. Living juveniles from Kon Plong protected forest, Kon Tum Province.

GNATHOCHILARIUM. Stipites distally with ovoid, poorly sclerotized, hairless area in middle of which small sclerotized 'island' carries one single spine-like seta.

COLLUM (Fig. 3A). Lateral lobe anteriorly with large, smooth, rounded, protruding extension; posteriorly with rectangular corner and several wrinkles.

BODY RINGS. With slightly vaulted metazona and with distinct longitudinal striation on metazona, more distinct on ventral parts but extending to dorsal parts as well; ozopores small, situated up to $2 \times$ their diameter behind suture. No sigilla.

EPIPROCT (Fig. 3B). With long, straight process protruding beyond paraprocts. Paraprocts smooth, with rounded margins ('lips').

STERNA. Smooth, stigmatal grooves short and shallow, reaching to tip of coxae.

LEGS. Relatively long; tarsi, tibiae and part of postfemora visible from above when legs are extended laterad. Length of podomeres: femur \approx tarsus $>$ tibia $>$ prefemur $>$ postfemur $>$ coxa $>$ claw. Claw slender, length almost $4 \times$ proximal height, no accessory claw. Prefemora dorsally with blunt longitudinal ridge. Coxae of seventh pair of legs not modified. Setation of posterior leg from a midbody ring: coxa: 5 ventral setae; prefemur: 3 dorsal spine-like setae, one long and several short, ventral fine setae; femur: 4 ventral fine setae; postfemur: 3 ventral fine setae; tibia: no setae; tarsus: 1 apicodorsal and 4 ventral

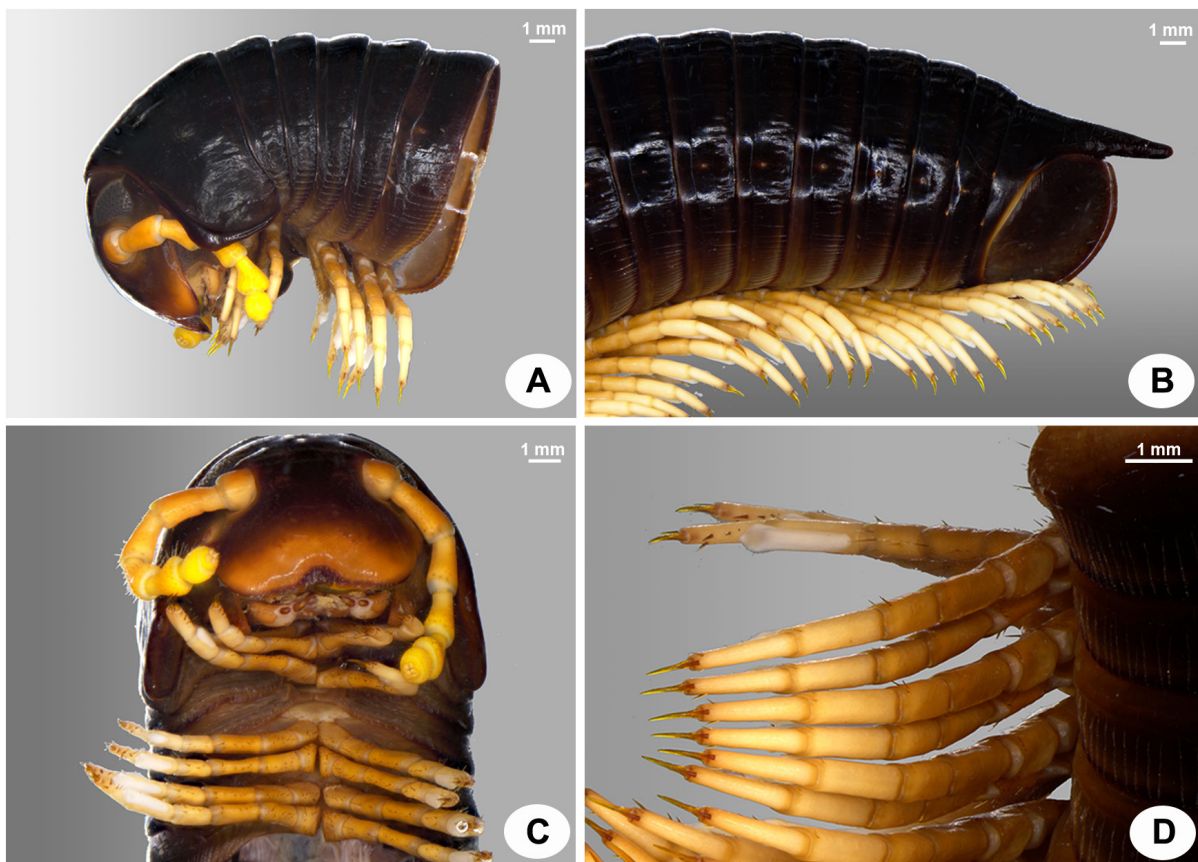


Fig. 3. *Alienostreptus bicoloripes* sp. nov., holotype (RBINS I.G.33.769/001). **A.** Head and anterior body rings, lateral view. **B.** Ultimate body rings, lateral view. **C.** Head and anterior body rings including seventh pair of legs, ventral view. **D.** Legs showing soft ventral pads, lateral view.

spinellike setae. Ventral pads (Fig. 3C–D) only on tibiae, on all legs except first two pairs, pad relatively long, distal ends overlapping ca $\frac{1}{3}$ of tarsi, terminating in triangular projection.

GONOPODS (Figs 4–5). Sternum absent. Paracoxites (*px*) forming small triangular lobe laterally at base of coxae. Coxae oval, apically rounded. Anterior coxal folds (*ac*) (Figs 4A, 5A) oval (narrower than in *A. alienus*), forming V-shaped longitudinal trough in anterior view, each *ac* concave in posterior view;

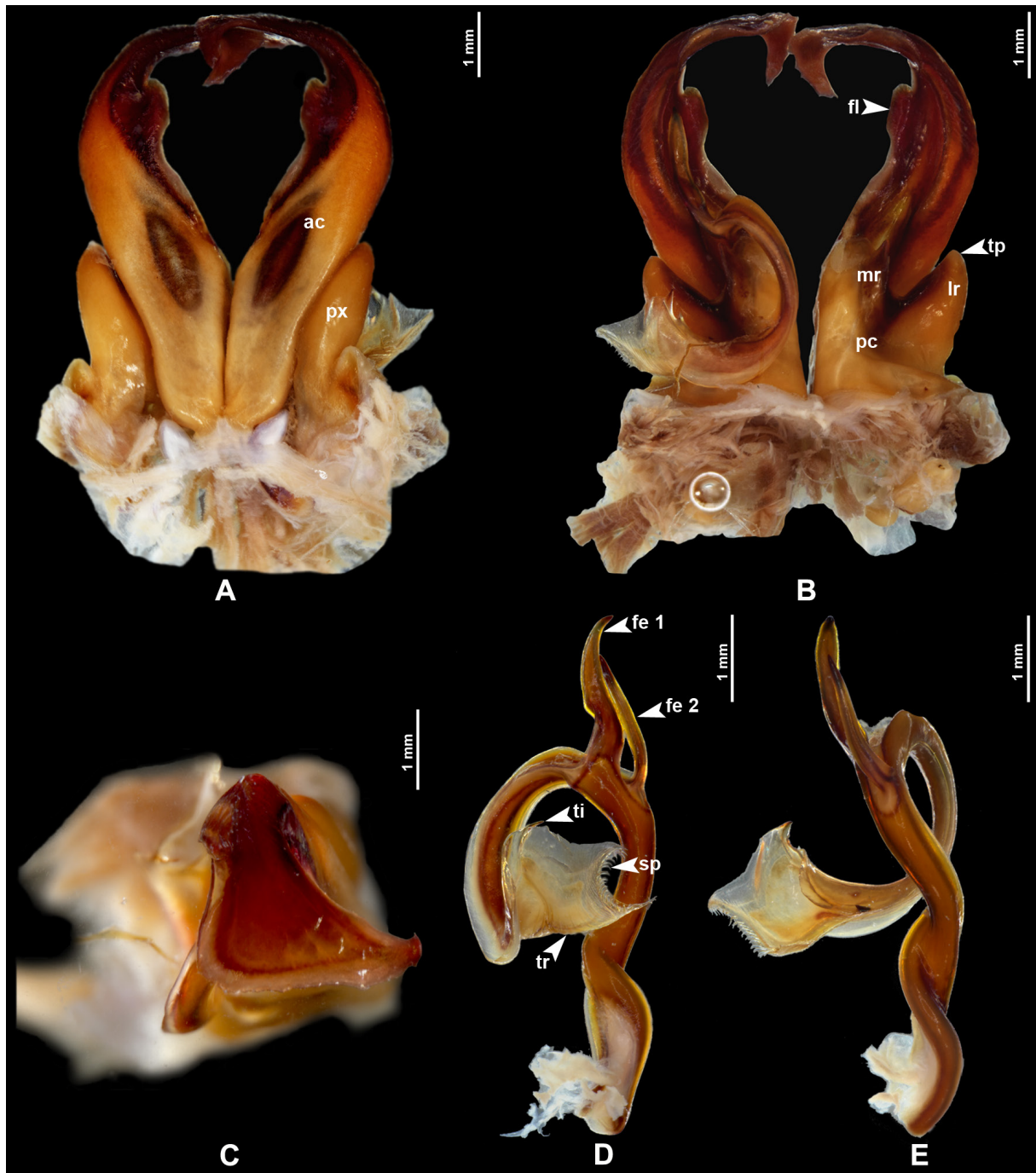


Fig. 4. *Alienostreptus bicoloripes* sp. nov., holotype (RBINS I.G.33.769/001). **A.** Anterior gonopod, anterior view. **B.** Anterior gonopod, posterior view. **C.** Left gonopod coxa, apical view. **D.** Left telopodite, posterior–mesal view. **E.** Left telopodite, anterior–lateral view.

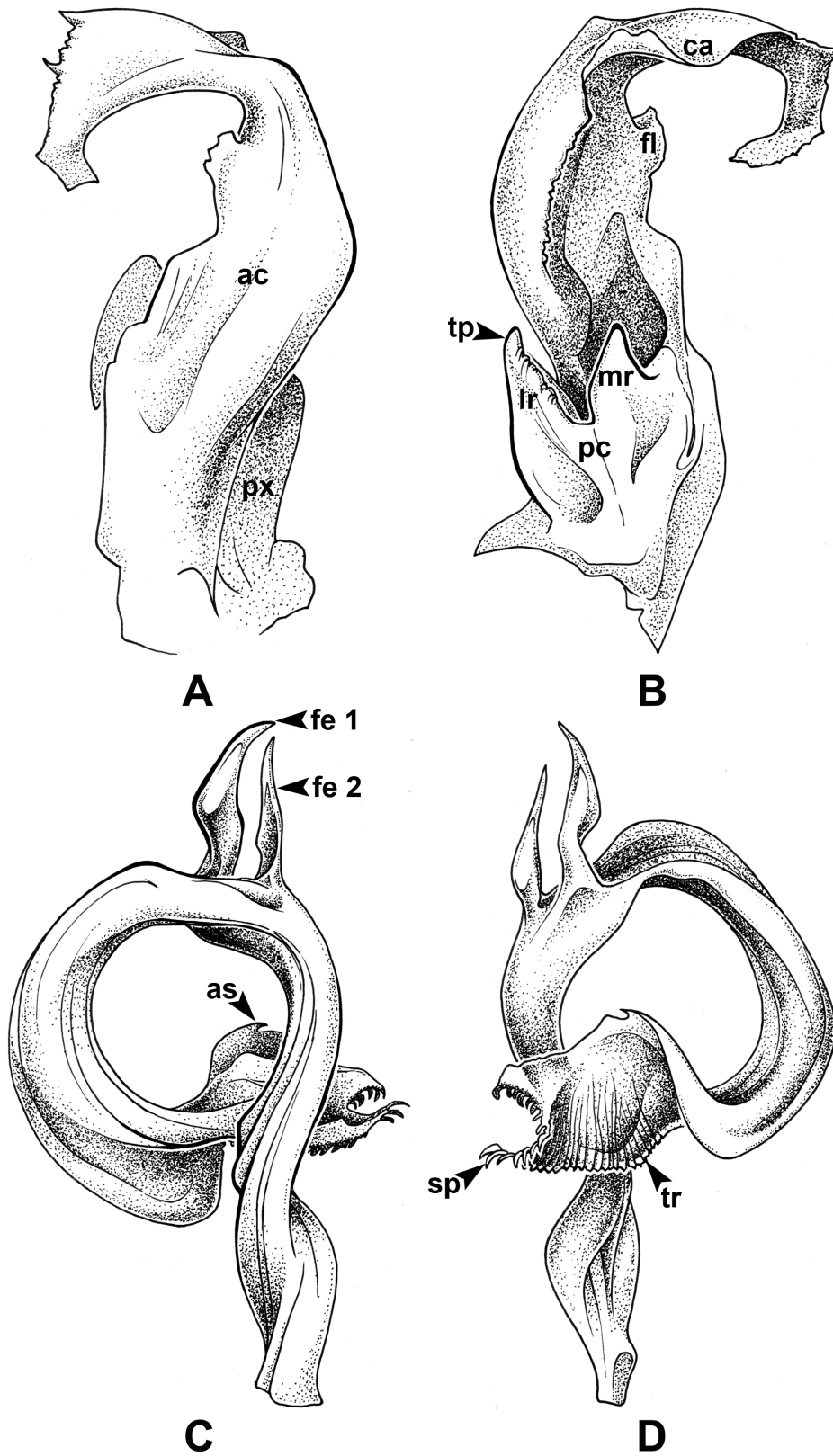


Fig. 5. *Alienostreptus bicoloripes* sp. nov., paratype (ZMUM). **A.** Right anterior gonopod, anterior view drawing. **B.** Right anterior gonopod, posterior view drawing. **C.** Left telopodite, posterior–mesal view drawing. **D.** Left telopodite, anterior–lateral view drawing.

mesally with one mesad lobe (*fl*), bluntly triangular in outline; distally with flattened, sickle-shaped lobe having mesal broad, rounded expansion forming canopy (Fig. 4 C). Posterior coxal fold (*pc*) (Figs 4B, 5B) very low, less than half as high as *ac*, consisting of two low, parallel ridges separated by smooth trough; lateralmost ridge (*lr*) with small, pointed triangular process (*tp*) laterally; mesal ridge (*mr*) continuing as sagittal ridge ending in small flap-like lobe (*fl*). Telopodite (Figs 4D–E, 5C–D) leaving coxite over posterior coxal fold; femoral spine duplicated (*fe1*, *fe2*), *fe1* very long, broader than *fe2*, straight, concave at $\frac{1}{3}$ of mesal margin, terminally slightly curved, ending in sharp point; *fe2* slender, very long, as long as *fe1*; tibial spine (*ti*) short, slender. Apical part of telopodite a broadly expanded sheet, with additional spine (*as*) at base, with row of setalike spines (*sp*) laterally, with several transverse ridges (*tr*) across along outer rim surface.

Females

Adult females (paratypes) with 59–60 podous rings, no apodous rings. Length 16–18 cm, width 13.4–13.9 mm.

Other non-gonopodal characters as in male, except:

- antennae not reaching past collum
- mandible without stipital lobe
- gnathochilarium without poorly sclerotized area on stipes
- collum with more rounded corners

LEGS. Shorter, tarsi and part of tibiae visible from above when legs extended laterad. Length of podomeres: femur > tarsus > tibia > prefemur \approx postfemur > coxa > claw. Setation of a posterior leg from midbody ring: coxa with 7 ventral setae; prefemur with 7 dorsal spinelike setae, 1 apocodorsal and several ventral fine setae; femur with 5 ventral fine setae; postfemur with 1 apicodorsal and 4 ventral fine setae; tibia with 1 apicodorsal and 5 ventral fine setae; tarsus with 1 dorsal and 4 ventral spinelike setae.

Distribution

Gia Lai and Kon Tum provinces, Vietnam (Fig. 8).

Ecology

Alienostreptus bicoloripes sp. nov. is found in a mixed tropical forest, formed mainly by broadleaf trees with tree ferns (*Cyathea* Sm. sp. and others) (Fig. 6A–D). At Kon Chu Rang Nature Reserve, adults were active in the daytime as well as at night. Juveniles were hiding all the time. Adults were distributed over a wide range of habitats, from the very bottom of valleys to the dry ridges with coniferous forest, which is not very typical of millipedes. The second visit to the Kon Chu Rang Nature Reserve was almost one and a half months earlier than the first one (26 March–6 April 2018), in early spring, and it was obviously the peak of this species' abundance. Numerous juveniles were observed along the streams in valleys (Fig. 2D). They mainly occupy a very specific habitat avoided by all other millipedes, viz, soaking wet clumps of leaf litter at the edge of streams and rivers, and also a surrounding area with a gradually decreasing water content. Leaf litter clumps caught by stones in streams also appeared as a habitat for juveniles. Sometimes they occupy troughs formed by rotten fallen trees next to the stream, which also contain a thick layer of wet leaf litter. Juveniles form loose aggregations in certain patches. They spend a few days in one spot, eating leaf litter and accumulating excrement in a 'chamber', then leave the 'chamber' and move to another spot. Juveniles may be resistant to acute flooding as the leaves

they inhabit are already soaking wet, and after frequent rains, the water level rises and covers most of the habitat. Three juveniles of later stages were found roaming around on leaf litter near the stream.

At Kon Plong protected forest, Kon Tum Province, Vietnam, (14°43' N, 108°18' E, 1050 m a.s.l.), we have not collected specimens due to technical issues. Adult specimens of *A. bicoloripes* sp. nov. were found exclusively on the surface of leaf litter on hill slopes above streams. Some were eating mushrooms, others roaming.

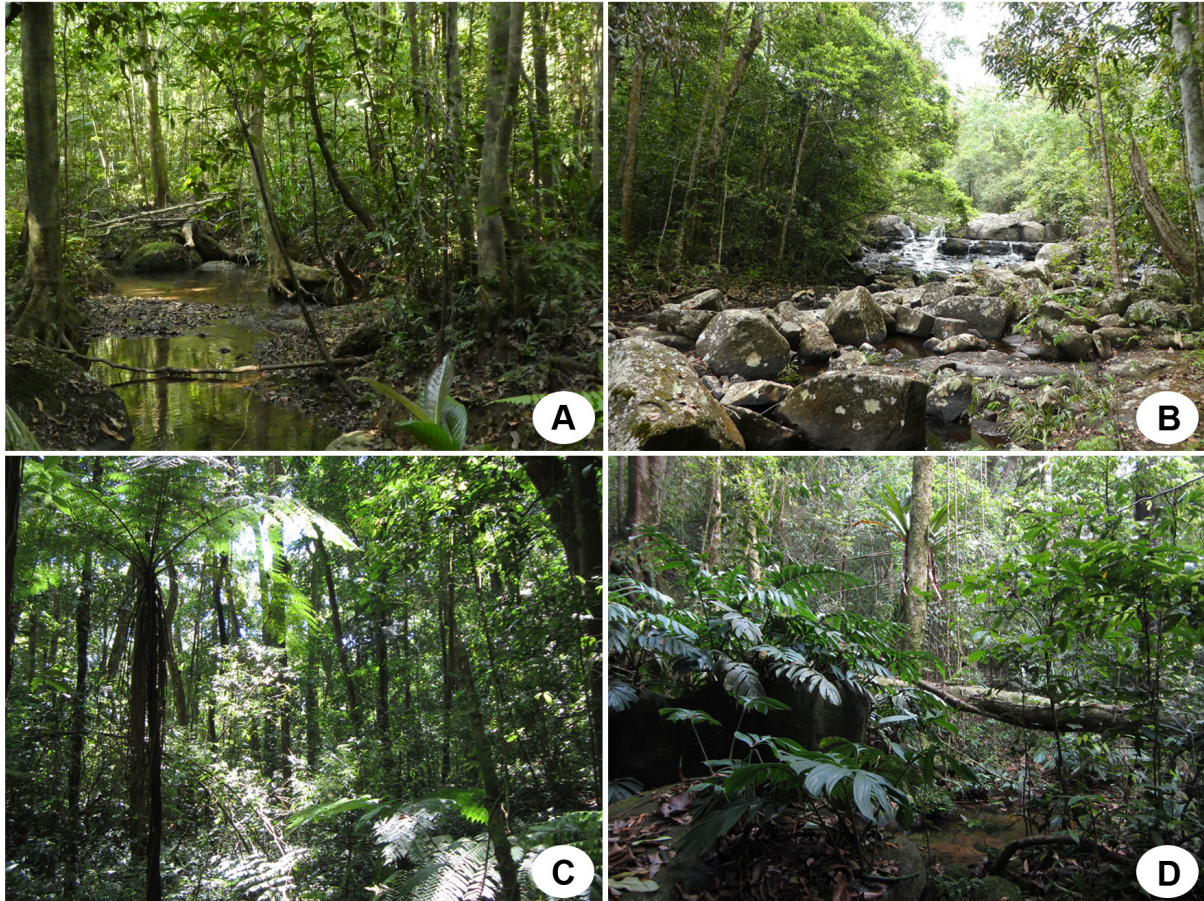


Fig. 6. Habitats of *Alienostreptus bicoloripes* sp. nov. in Vietnam. **A–C.** Kon Chu Rang Nature Reserve, Gia Lai Province. **D.** Kon Plong protected forest, Kon Tum Province.

A ‘copycat’ specimen from Borneo?

Clement Sim, Peter Petersen and Nicky Bay have taken photographs of a giant millipede from Kuching (Fig. 7A), Matang (1°36'46.4" N, 110°12'10.5" E) (Fig. 7B), and Kubah National Park near Kuching (Fig. 7C–D), Borneo (Malaysia: Sarawak) which has a very similar colour to that of *A. bicoloripes* sp. nov. According to the photos, there are, however, differences (Table 1).

Specimens from Borneo are not available. However, despite the unusual colour pattern shared with *A. bicoloripes* sp. nov., it is clear that it belongs to a different genus, based on the presence of ventral soft pads on the postfemora of the male legs.

Table 1. Morphological differences between *A. bicoloripes* sp. nov. and Borneo specimens.

	Borneo specimens	<i>A. bicoloripes</i> sp. nov. from Vietnam
Body colour	brown to dark brown	dark brown (almost black)
Antennae	pink	bi-coloured (as legs)
Legs	from coxae to postfemora pink, tibiae and tarsi yellow	from coxae to postfemora brownish orange, tibiae and tarsi pale yellow
Ventral soft pads	present on both postfemora and tibiae	present only on tibiae

Discussion

The millipede subfamily Rhynchoproctinae currently comprises 36 species in 14 genera. As mentioned in Pimvichai *et al.* (2010), members of the subfamily form a monophyletic group by sharing three synapomorphic characters. However, the genus *Alienostreptus* differs from all other genera in the subfamily by having the femoral spine duplicated.

The photographed Bornean specimens (Fig. 7) show a similar colour pattern to that of the type specimens of *Alienostreptus bicoloripes* sp. nov., but there are differences in some details (see above). In the pet trade, there is a millipede looking similar to the Bornean specimens, it is sometimes referred to as



Fig. 7. Specimens from Borneo (Malaysia: Sarawak). **A.** Living female from Kuching (Photo by Clement Sim). **B.** Living male from Matang (Photo by Peter Petersen). **C–D.** Living male from Kubah National Park (Photos by Nicky Bay).

Trigoniulus macropygus (Silvestri, 1897) – a blatant misidentification – or Flameleg millipede, originally also from Borneo and published on the internet, <https://www.youtube.com/watch?v=Vw3IT5d4PiI> and <https://www.pinterest.dk/pin/411164640984124717/?autologin=true>. We have reviewed original and subsequent descriptions of all 29 harpagophorid species listed from Borneo by Jeekel (2006). Many of the descriptions include notes on leg colour, but only for two species the description more or less reminds of *A. bicoloripes* sp. nov. These are two species of the endemic Bornean genus *Lamellostreptus* Demange, 1961:

Lamellostreptus complexus (Chamberlin, 1921), described from “Sarawak, Poak, near Kuching”: “Legs and antennae pale ferruginous, with the first two articles darker, brownish” (Chamberlin 1921: 63).

Lamellostreptus seriatus Demange, 1961, described from “Borneo”: “Antennes et pattes jaune-rouge tranchant sur la coloration foncée du corps” (antennae and legs yellow-red, contrasting with the dark body colour) (Demange 1961: 66).

With the reservation that the descriptions of these (and other Bornean) species were based on preserved specimens, this suggests that the Bornean ‘copycat’ of *Alienostreptus bicoloripes* sp. nov. may be a species of *Lamellostreptus*, subfamily Harpagophorinae. In order to establish the identity of the Bornean species with certainty, a study of a male specimen is, however, needed.

Many tropical millipedes have pronounced seasonal differences in activity, often the males come out first, and then females arrive into the community. Males also disappear first, so at the end of the species’ season, there are mainly females in the community.

Different areas have different climatic features, so the millipede communities at Kon Plong and Kon Chu Rang have a different timing of seasonal abundance, but for Kon Chu Rang we can assume that early spring is the peak season of *A. bicoloripes* sp. nov., with a fast decline in abundance over a few months until the absolute absence of adults.

The body colour changes with the age of the millipede. If juveniles are pale beige with yellowish legs, more mature stages acquire a darker brown colour with pronounced yellow legs and antennae, and then adults get the final coal black body with bright yellow legs and antennae fading into red basally. At one point, there were at least three distinct age stages present in the community: juvenile medium size, juvenile later stage and adults. Juveniles of very first stages were not found. Based on this, we can assume that the life cycle of this species takes at least three years: two years of development and then one as an adult.

The striking colour pattern invites considerations about function. One possibility is that the colours are aposematic. However, living individuals of *A. bicoloripes* sp. nov. are not very willing to secrete their defensive fluids – only when placed in alcohol, they start excreting. The ‘warning’ may therefore refer to the particularly strong cuticle of *A. bicoloripes* sp. nov., rather than the chemical defence. At Cat Tien National Park in South Vietnam, many remnants of another harpagophorid, *Thyropygus carli* Attems, 1938, were found in mammalian excrements, but remnants of *A. bicoloripes* sp. nov. were never found in this substrate. Finally, a mimetic function cannot be excluded; although an obvious mimetic model has not been observed in Vietnam, the long colourful legs might suggest a scolopendrid centipede. In any case, the similarity of the colour patterns of *A. bicoloripes* sp. nov. and the so far unidentified, but most probably not congeneric Bornean species, is remarkable.



Fig. 8. Known distribution of *Alienostreptus* Pimvichai *et al.* 2010 spp. and superficially similar specimens from Borneo. Droplets vary in size only to improve readability.

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