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## Research article

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# A new genus of the millipede tribe Brachyiulini (Diplopoda: Julida: Julidae) from the Aegean region

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**Abstract.** A new genus of the julid tribe Brachyiulini, *Enghophyllum* gen. nov., is described, comprising two species from Greece. The type-species, *E. naxium* (Verhoeff, 1901) comb. nov. (ex *Megaphyllum* Verhoeff, 1894), appears to be rather widespread in the Aegean: it is known from Antiparos Island and Naxos Island (the type locality), both in the Cyclades, as well as East Mavri Islet, Dodecanese Archipelago (new record). The vulva of *E. naxium* is described for the first time. In addition, *E. sifnium* gen. et sp. nov. is described based on a single adult male from Sifnos Island, Cyclades. The new genus is distinct from other genera of the Brachyiulini mainly by its peculiar gonopod structure, apparently disjunct and at least mostly apomorphic: (1) promeres broad, shield-like, *in situ* protruding mostly posteriad, completely covering the opisthomeres and gonopodal sinus; (2) transverse muscles and coxal apodemes of promere fully reduced; (3) opisthomere with three differentiated processes, i.e., lateral, basal posterior and apical posterior; (4) solenomere rather simple, tubular. The evolution and biogeography of the new genus are briefly discussed, both suggesting its profoundly long isolation in the Aegean region from the conribal genera in the adjacent Balkans and Anatolia.

**Key words.** *Brachyiulus*, *Chromatoiulus*, *Megaphyllum*, new taxa, new records.

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## Introduction

The present paper continues our efforts in revising the large julid tribe Brachyiulini (Lazányi *et al.* 2012; Lazányi & Vagalinski 2013; Vagalinski *et al.* 2013), this time being devoted to the description of a new oligotypic genus from several Aegean islands of Greece. Its type species, *E. naxium* (Verhoeff, 1901), previously referred to as *Brachyiulus naxius*, *Chromatoiulus (Diaxylyus) naxius* or *Megaphyllum naxium*, has been found to occur both in the Cyclades and Dodecanese archipelagos, whereas the second congener, *E. sifnium* gen. et sp. nov., is a new species described below. The gonopod and, to some degree, the

vulval structures of these two species appear to be of great interest by shedding additional light on the evolution and biogeography of the entire fauna of eastern Mediterranean Brachiulini.

## Material and methods

The present work is based on the examination of material from the Non-insect Invertebrate Collection, National Museum of Natural History (NMNHS), Sofia, and the Natural History Museum of Denmark, Zoological Museum, University of Copenhagen (ZMUC). Types of the new species are deposited in ZMUC. Specimens are stored in 70% ethanol and small dissected parts have been placed in genitalia vials which are kept together with the dissected individuals. Female vulvae were mounted on slides in Faure-Berlése medium and incubated at room temperature (around 25°C) for several hours. After having been studied, the slides were put into distilled water, vulvae were removed from the Faure-Berlése medium and put into 70% ethanol.

Line drawings were made with a Leica M125 (HNHM) stereo microscope and an Olympus BX40 light microscope.

The apical end of the opisthomere is distinguished as the solenomere; all processes emerging from the opisthomere's main body are named simply according to their position as lateral, basal and apical posterior processes.

## Results

Class Diplopoda Blainville-Gervais, 1844  
Order Julida Leach, 1814  
Family Julidae Leach, 1814  
Tribe Brachiulini Verhoeff, 1909

Genus *Enghophyllum* gen. nov.

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## Type species

*Brachyiulus (Chromatoiulus) naxius* Verhoeff, 1901

## Diagnosis

A genus of Brachiulini, differing from contribal genera by the following combination of characters: promere broad, shield-like, *in situ* protruding mostly posteriad, completely covering opisthomere and gonopodal sinus; transverse muscles and coxal apodemes of the promere fully reduced. Opisthomere with 3 well-differentiated processes: lateral (*lp*), basal posterior (*bpp*) and apical posterior (*app*). Solenomere rather simple, tubular.

## Etymology

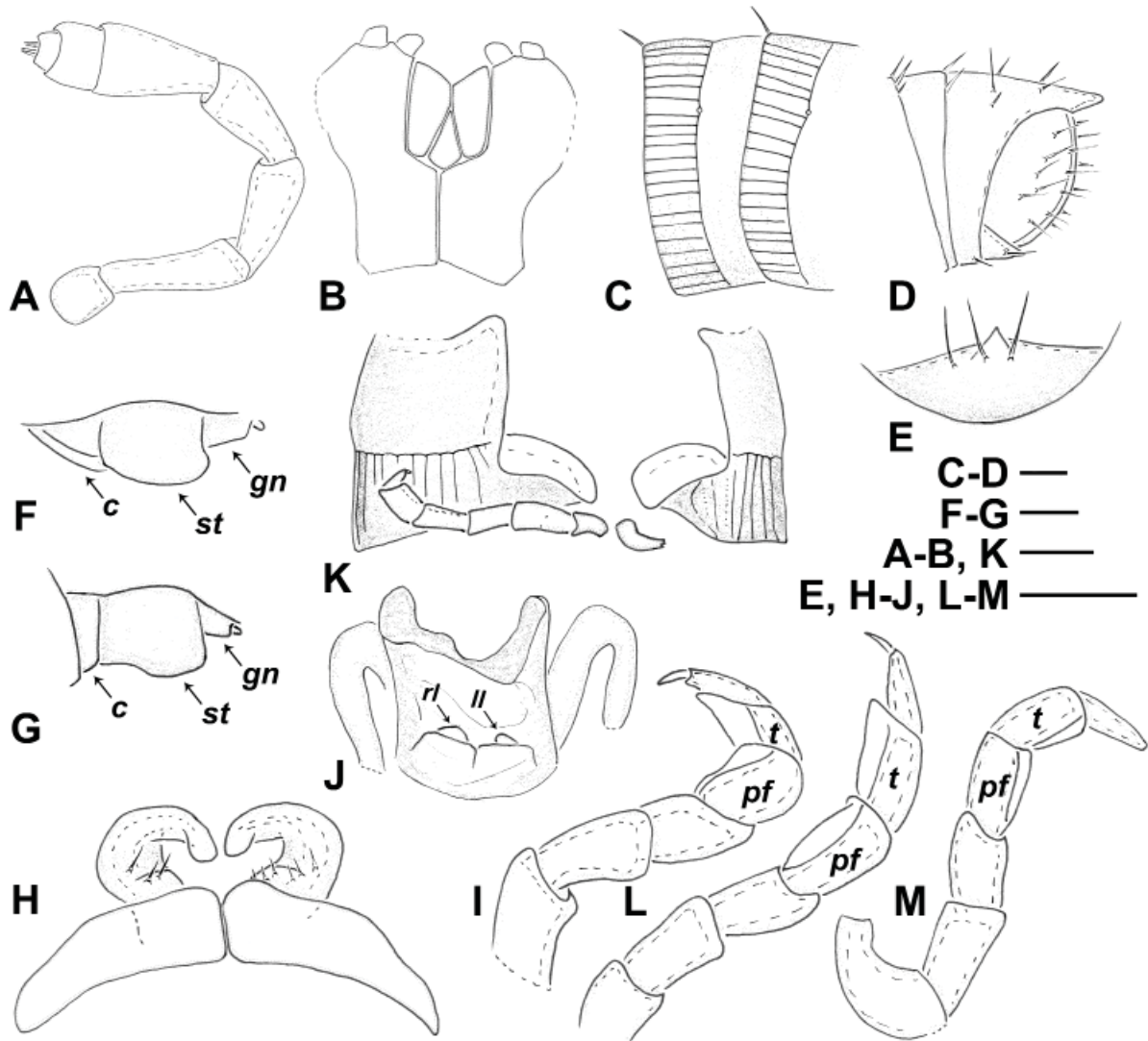
This genus is named in honor of Prof. Henrik Enghoff from the ZMUC, not only for his vast contribution to our knowledge of diplopods, but also for his continuous encouragement and help during our work with Brachiulini.

## Description

Two frontal, four supralabral and 14-18 labral setae. Antennomeres 4 and 5 subequal in length (Fig. 1A). Gnathochilarium as on Fig. 1B. Metazona sparsely striated, as emphasised by Verhoeff (1901); ozopores right on the suture (Fig. 1C). Preanal process straight, anal valves sparsely pilose (Fig. 1D); subanal scale triangular, with protruding tip (Fig. 1E).

**Males**

Mandibular stipes slightly protruding (Fig. 1F-G). First leg-pair like simple, rounded, somewhat converging hooks; the two hooks converging in an obtuse angle (Fig. 1H). Second leg-pair (Fig. 1I) with two ventral pads: on postfemur (*pf*) and tibia (*t*). Penis (Fig. 1J) significantly small, deeply hidden in penis sac, with two very short lobes and two rounded small lamellae running parallel, i.e., not diverging (*rl* and *ll* for right and left lamella). Pleurotergum of the 7<sup>th</sup> body ring protruding like a simple shovel (broken in the unique holotype of *E. sifnium* gen. et sp. nov., thus investigated only in *E. naxium*, see Fig.



**Fig. 1.** Non-gonopod characters of *Enghopyhllum* gen. nov., males. **A.** Right antenna. **B.** Gnathochilarium. **C.** 8<sup>th</sup> and 9<sup>th</sup> body rings. **D.** Telson. **E.** Subanal scale. **F.** Mandibular stipital (“cheek”) lobe, lateral view. **G.** Mandibular stipital (“cheek”) lobe, ventro-lateral view. **H.** First leg-pair. **I.** Second leg-pair. **J.** Penis in the penis sac. **K.** Pleurotergum of the 7<sup>th</sup> body ring, ventral view. **L.** Anterior left leg on the 6<sup>th</sup> body ring. **M.** Anterior right leg on the 22<sup>nd</sup> body ring. – A-D, F, H-I, L-M: *E. sifnium* gen. et sp. nov., holotype. E: *E. naxium*, from Antiparos. G, J-K: *E. naxium*, from Mavri Islet.

1K). Walking legs (Fig. 1L-M) with two ventral pads: on postfemur (*pf*) and tibia (*t*). Tarsus of midbody legs slightly longer than tibia: tarsus / tibia = (1.05-1.1) / 1.

Gonopods noticeably big compared to body size, directed mostly posteriad. Promere bevelled in latero-basal corner to fit into the inner curve of the 7<sup>th</sup> body ring; latero-basal corner of promere only with thin triangular lamella (*tl*) (Fig. 2D-E). Promeres attached to each other in their meso-basal corner with a chitinous bridge. A short, oblique ridge (*r*) on posterior surface of promere (Figs 2A, D-E, 4A, C). Flagellum emerging from a well-developed sinus (*fsi*) (Fig. 2D-E). At the level of this sinus a deepening on anterior surface of the promere (*d*) (Fig. 4B). Opisthomere entirely concealed under the promere, protruding postero-ventrad, the two promeres tightly closing the ventral opening on 7<sup>th</sup> ring like a pair of shutters. Opisthomere not embedded in the groove formed by the oblique ridge on the promere's posterior surface (unlike in *Megaphyllum*), but "riding" on the ridge (Figs 2A, 4C): posterior basis of opisthomere with a characteristic ruffle (*ri*) formed by chitinous lamellae, where the ridge of the promere is positioned (Figs 2A, G, 4C-D). Opisthomere with a well-developed lateral process (*lp*) and an apical and a basal posterior process (*app* and *bpp*). Solenomere (*s*) simple, with no processes but basally with a micro-spinose pillow (*msp*) (Figs 2A-C, F-G, 4A-D). Flagellum channel and sperm canal (*fc* and *sc*) each with an apical opening (Fig. 4C).

### Females

The only available female of *E. sifnium* gen. et sp. nov. is in stadium IX (with 8 rows of ocelli) and proved to be subadult, but females of *E. naxium* in stadia VIII-IX (with 7-8 rows of ocelli) had fully developed vulvae, which we used here for the description of female sexual characters. First two leg-pairs slightly swollen.

Vulva (Fig. 3): Subcylindric in shape, the mesal half shorter, the opening large, oval, apical. Operculum shorter than bursa, with around 20-25 setae. Mesal and lateral sclerites with 2-3 setae each. Apodematic tube not opening apically into a longitudinal median cleft as in, e.g., *Megaphyllum* species, but into a wide sinus (*si*). Around this sinus a thin wall, formed by the apical part of the bursa. These walls with small dot-like pores; most setae (around 20/side) emerging from this apical region. Apodematic tube (*at*) ending in two receptaculi seminis or ampullae. Central ampulla (*ca*) drop-like. Distal, globular ampulla (*da*) joining the apodematic tube through a twisted connecting tube (*ct*). Connecting tube very long, thus the distal ampulla hanging out of the bursa; easily broken off during preparation.

### Remarks

The everted penes of the adult *E. naxium* male from Antiparos was quite soft, amorphous and huge, contrary to the stout, minute penes, deeply hidden under the 2<sup>nd</sup> leg-pair coxae, observed in the *E. naxium* male from Mavri Islet and the *E. sifnium* gen. et sp. nov. male from Sifnos. It is possible that penes vary in size between copulating and non-copulating periods.

*Enghophyllum sifnium* gen. et sp. nov.

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Figs 1A-D, F, H-I, L-M, 2A-G, 5

### Diagnosis

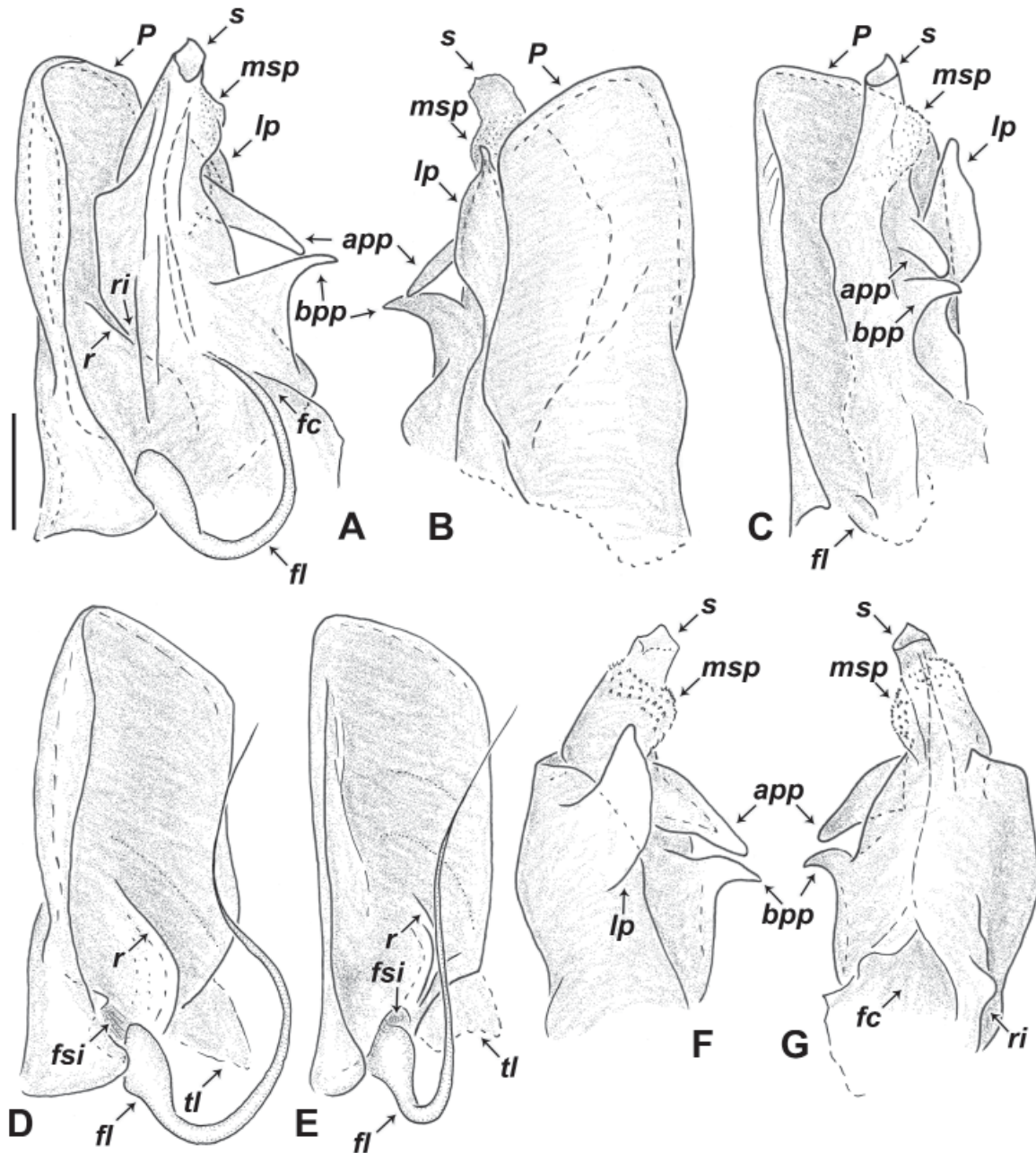
Differs from the only congener, *E. naxium* (Verhoeff, 1903), by the apical margin of the promere being slightly convex and the opisthomere being significantly compressed meso-laterad.

### Etymology

Named after the type locality, the island of Sifnos, Cyclades.

**Material examined****Holotype**

GREECE: ♂, Hellas [Greece], Kikladhes [Cyclades], Sifnos Island, Pharos [Faros], 11.ii.1990 [11 Feb. 1990], S. Sfendourakis leg., ex coll. Karamaouna, “*Megaphyllum* aff. *naxium* (Verhoeff, 1901)” M. Karamouna det. (ZMUC).



**Fig. 2.** Gonopods of *Enghophyllum sifnium* gen. et sp. nov., holotype ♂. **A.** Left gonopods, mesal view. **B.** Left gonopods, antero-lateral view. **C.** Left gonopods, meso-posterior view. **D.** Left promere, meso-posterior view. **E.** Left promere, postero-mesal view. **F.** Right opisthomere, lateral view. **G.** Right opisthomere, mesal view. – *app* = apical posterior process; *bpp* = basal posterior process; *fc* = flagellum channel; *fl* = flagellum; *fsi* = flagellum sinus; *lp* = lateral process; *msp* = micro-spinose pillow; *P* = promere; *r* = ridge; *ri* = ruffle; *s* = solenomere; *tl* = triangular lamella. Scale bar: 0.2 mm.

### Paratypes

GREECE: 1 juv. ♂, 1 juv. ♀. Same collection data as holotype (ZMUC).

### Description

Holotype male in stadium X (with 9 rows of ocelli); body ring number: 41 podous + 2 apodous + telson; length 18.8 mm; height 1.1 mm; ocelli: right side: 35, left side: 33. Additional measurements of the adult male: promentum around twice as long as wide (Fig. 1B), tibia of midbody legs slightly longer than tarsus, 4<sup>th</sup> antennal article as long as 5<sup>th</sup> (Fig. 1A). Subadult paratype male in stadium IX (with 8 rows of ocelli); body ring number: 38 podous + 3 apodous + telson; length 13.1 mm; height 1.1 mm; ocelli: right side: 34, left side: 35. Subadult female in stadium IX (with 8 rows of ocelli); body ring number: 39 podous + 3 apodous + telson; length 14.1 mm; height 1 mm; ocelli: right side: 30, left side: 30. 17-18 labral bristles.

COLOUR. Basic colour yellowish-beige (obviously faded) with a narrow brownish middorsal band, divided by a white median line. Two wider, diffused brownish bands at ozopore level, more intensely coloured around the ozopores.

SCULPTURE. Collum smooth, with only several short striae visible; metazona sparsely striated (Fig. 1C), somewhat denser on dorsal side, posterior margin with long, erect setae. Scarce, short striae also on prozona.

TELSON (Fig. 1D). Anal valves covered with scarce, long setae and a row of much shorter setae along each valve's caudal margin. Preanal process without any setae in the adult male, but with a few setae in the two subadults; straight, stout, protruding near to the level of the longest anal setae (for the adult male). Subanal scale triangular, with a rounded tip, slightly protruding behind rear contour of anal valves; with two pairs of long setae laterally.

GONOPODS (Fig. 2A-G). Promere (Fig. 2D-E and *P* on Fig. 2A-C) wide, slightly narrowing apically towards mesal margin. Apical margin convex, mesal and lateral margins almost parallel, the lateral one slightly sinuous. Opisthomere with three processes: a flat lateral process (*lp* on Fig. 2A-C, F), a slightly curved, rod-like basal posterior process (*bpp* on Fig. 2A-C, F-G) and an elongate, massive, rod-like apical posterior process (*app* on Fig. 2A-C, F-G); all processes well-developed, tapering and not furcated. A micro-spinose pillow (*msp*) around the base of solenomere (*s*) (Fig. 2A-C, F-G). Entire opisthomere strongly compressed meso-laterad (compare Fig. 2C with Fig. 4A).

Female adults unknown.

### *Enghophyllum naxium* (Verhoeff, 1901) comb. nov.

Figs 1E, G, J-K, 3, 4A-D, 5

*Brachyiulus* (*Chromatoiulus*) *naxius* Verhoeff, 1901: 98-99, fig. 21.

*Chromatoiulus naxius* – Attems 1927: 222 (in key). — Strasser 1974: 290, 295. — Ceuca 1992: 425.

*Chromatoiulus* (*Diaxylyus*) *naxius* – Attems 1940: 307, 311-312.

*Megaphyllum naxium* – Mauriès & Karamaouna 1984: 55-56, figs 7-9. — Enghoff & Kime 2009. — Lazányi *et al.* 2012: 21, 41.

### Diagnosis

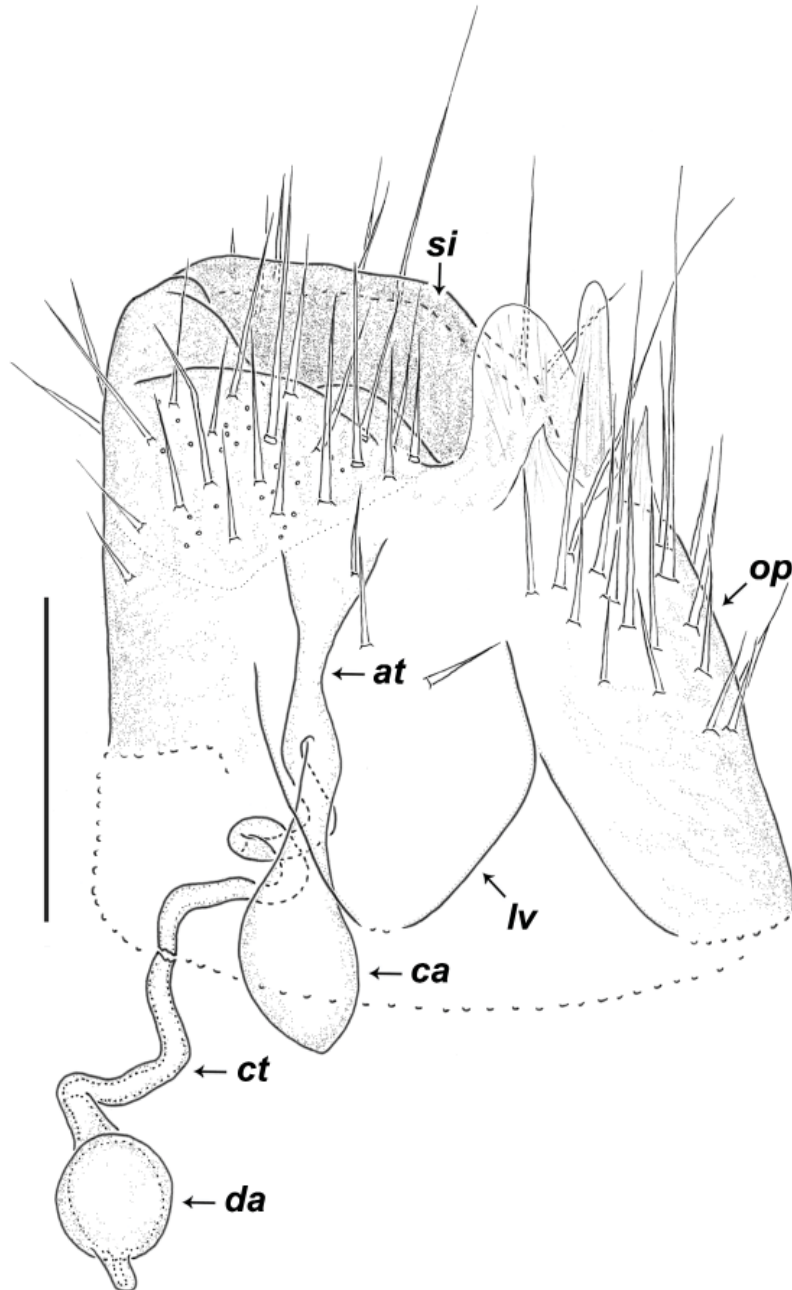
Differs from the only congener *E. sifnium* gen. et sp. nov. by the apical margin of the promere being concave, the opisthomere not compressed meso-laterad, e.g., the lateral process (*lp* on Fig. 4A-D) parallel to the promere, the lateral process (*lp*) much broader and the apical posterior process (*app*) broader and blunter.

### Material examined

GREECE: 1 ♂, 2 ♀♀, Antiparos Island, litière [litter], 22 Dec. 1982, leg. P. Beron & St. Andreev, det. Mauriès 1983 (NMNHS); 1 ♂, Sporadhes, Anatoliko Mauri [east Mavri Islet] (Levitha Islands), 18.i.1990 [18 Jan. 1990], S. Sfendourakis leg., ex coll. M. Karamaouna (ZMUC).

### Remarks

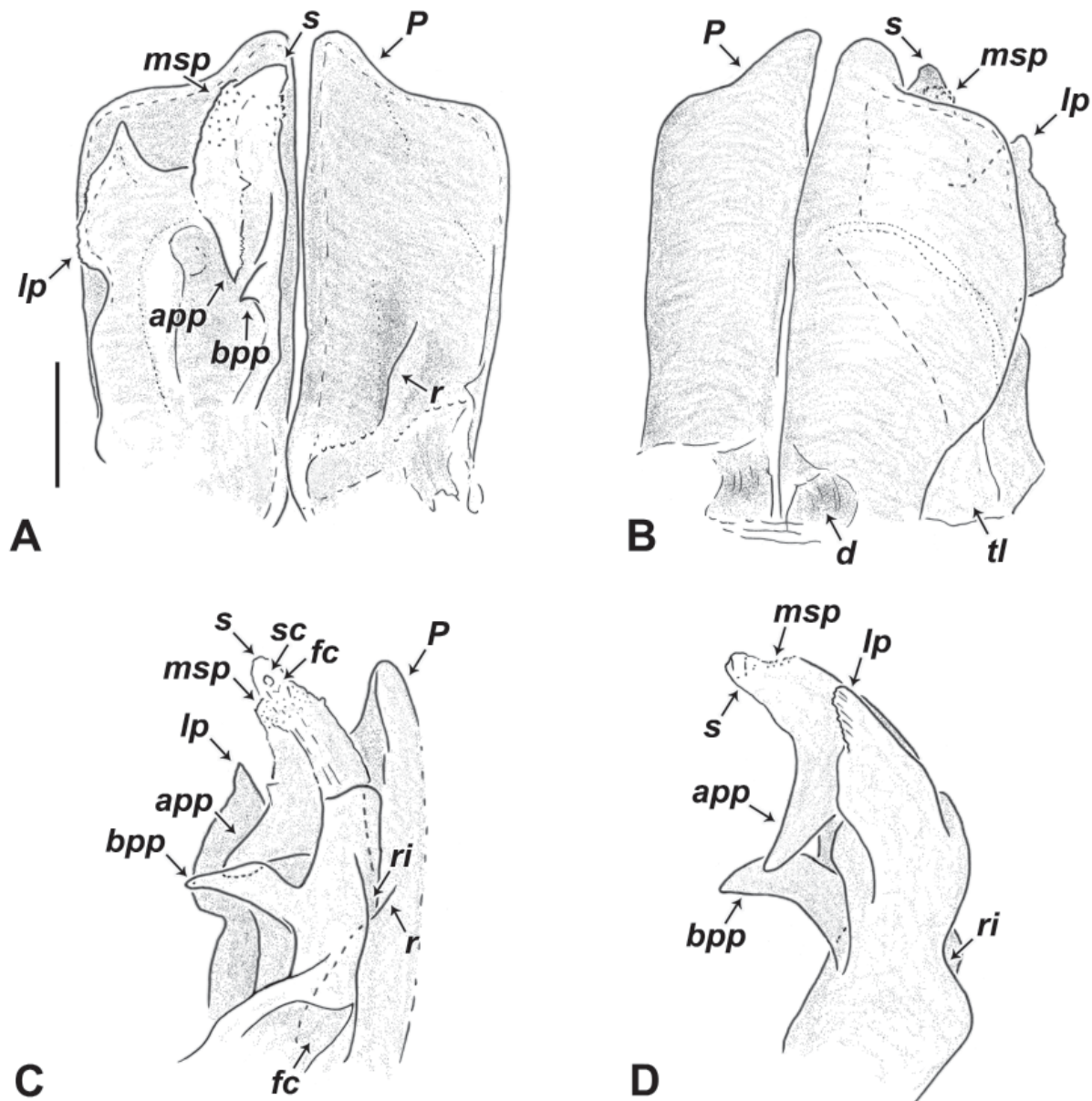
Male body length 16.9-17.9 mm; height 1-1.2 mm; body ring number: 39-41 podous rings + 2-3 apodous rings + telson; number of ocelli: right side: 30-38, left side: 32-38; developmental stadium IX-X with



**Fig. 3.** Right vulva of *Enghophyllum naxium*, female from Antiparos Island, anterior view. – *at* = apodematic tube; *ca* = central ampulla; *ct* = connecting tube; *da* = distal ampulla; *lv* = lateral valve; *op* = operculum; *si* = sinus. Scale bar: 0.2 mm.

8-9 rows of ocelli. Female body length 13.4-18.3 mm; height 1-1.3 mm; body ring number: 37-41 podous rings + 3-5 apodous rings + telson; developmental stadium VIII-IX with 7-8 rows of ocelli.

This species was described on the basis of two males and four females and has only been found once since its description, *viz.*, by Mauriès & Karamaouna (1984) from Antiparos. The new specimens from east Mavri belong to the collection of Karamaouna, but they are slightly different: the apical posterior process (*app*) of the solenomere is not bifurcated, but undivided and slightly serrated (serration visible in posterior view) (Fig. 4A, C-D).



**Fig. 4.** Gonopods of *Enghophyllum naxium*, male from Mavri Islet. **A.** Gonopods, posterior view. **B.** Gonopods, antero-lateral view. **C.** Right gonopods, mesal view. **D.** Left opisthomere, lateral view. – *app* = apical posterior process; *bpp* = basal posterior process; *d* = deepening; *fc* = flagellum channel; *lp* = lateral process; *msp* = micro-spinose pillow; *P* = promere; *r* = ridge; *ri* = ruffle; *s* = solenomere; *sc* = sperm canal; *tl* = triangular lamella. Scale bar: 0.2 mm.

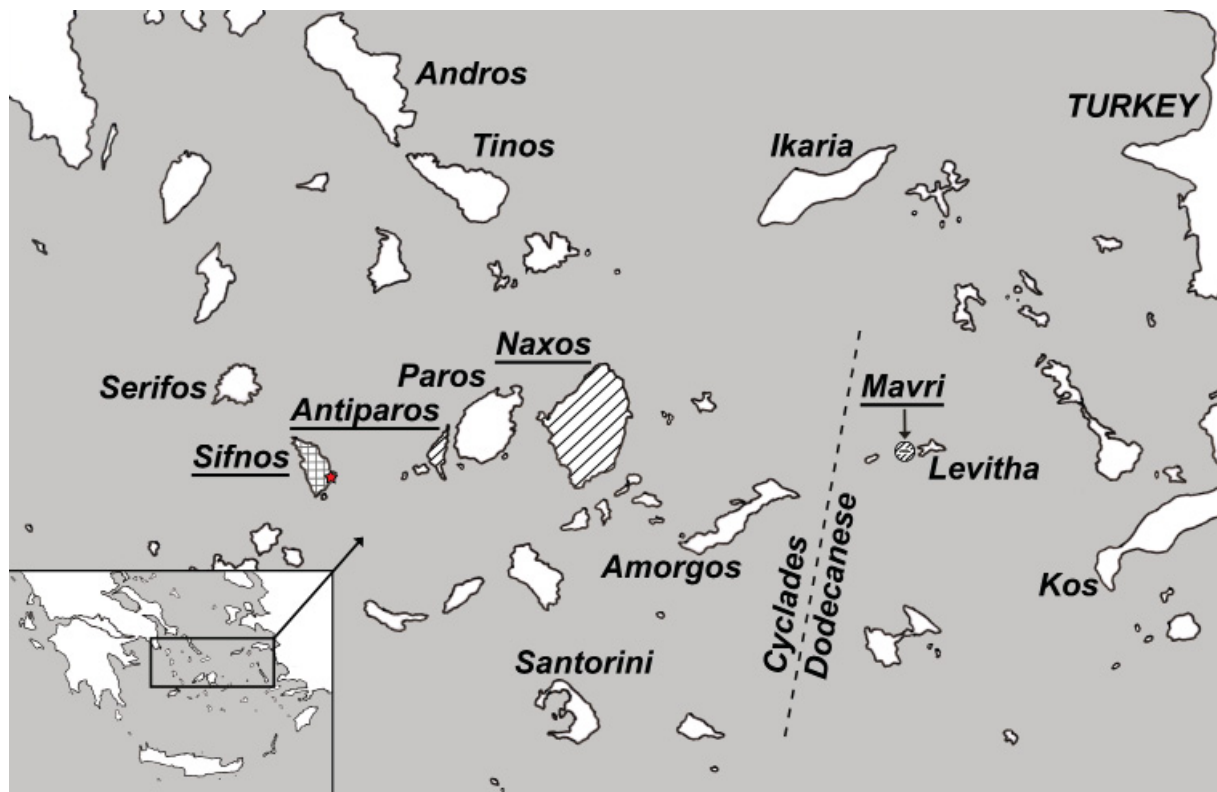


### Distribution

Greece: Cyclades: Naxos Island (type locality), Antiparos Island (Mauriès & Karamaouna 1984); Dodecanese Islands: east Mavri Islet.

### Discussion

*Enghophyllum naxium* was hitherto treated as a *Megaphyllum* species (or under its former synonyms *Chromatoiulus* and *Brachiulus s. auct.*) (Lazányi *et al.* 2012). It was placed in the subgenus *Diaxyllus* Attems, 1940 (type species: *Chromatoiulus anaticus* Attems, 1927) on the basis of having a simple promere, a simple solenomere, a posterior process at right angles to the opisthomere and lacking a bristle-row along the flagellum channel (Attems 1940). After thorough investigations of this species and of *E. sifnium* gen. et sp. nov., supplemented with the examination of *Megaphyllum argolicum* (Verhoeff, 1900), *M. asiaeminoris* (Verhoeff, 1898), *M. euphorbiarum* (Verhoeff, 1900) and *M. anaticum* (Attems, 1927), all referred to *Diaxyllus*, it became apparent that *E. naxium* and *E. sifnium* gen. et sp. nov. form a group neither with the aforementioned species, nor with any other *Megaphyllum* subgenus or Brachiulini genus. The combination of external morphological characters together with male and female genitalia characters supports the establishment of a new brachiuline genus: *Enghophyllum* gen. nov. Considering gonopodal structure, some similarities with *Megaphyllum byzantinum* (placed in the monotypic subgenus *Byzantorhopalum* Verhoeff, 1930) can be discerned, namely the well-developed lateral process of the opisthomere and the cylindrical vulvae with a mostly apically positioned opening. However, some external and internal features of the vulvae, the shape of the penes, and notably the unique arrangement of the promeres leave no doubt that these species belong to a different genus.



**Fig. 5.** Distribution map of *Enghophyllum* gen. nov. The checked area (Sifnos Island) represents the possible distribution of *E. sifnium* gen. et sp. nov.; the red star shows Faros, its type locality. The obliquely lined areas (Antiparos and Naxos Islands, Mavri Islet) show the distribution of *E. naxium*.

The known distribution of *Enghophyllum* gen. nov. is so far restricted to three islands in the Cyclades (Naxos, Antiparos and Sifnos) and one small islet in the westernmost part of the Dodecanese Islands, Greece (east Mavri Islet, Fig. 5). There are currently 10 other species of Brachyiulini reported from the Aegean Islands: *Brachyiulus stuxbergi* (Fanzago, 1875) (Crete), *Megaphyllum bicolor* (Loksa, 1970) (Rhodos, Naxos), *M. brachyurum* (Attems, 1899) (Thasos), *M. chiosense* Lazányi & Korsós, 2012 (Chios), *M. creticum* (Strasser, 1976) (Crete), *M. mueggenburgi* (Verhoeff, 1901) (Karpathos, Kasos), *M. rossicum* (Timotheew, 1897) (Samothraki), *M. sapphicum* (Strasser, 1976) (Lesvos), *M. syrense* (Verhoeff, 1903) (Syros) and *M. taygeti* (Strasser, 1976) (Crete) (Felesaki *et al.* 2010; Lazányi *et al.* 2012). Most of them are known only from a single island, except for *M. mueggenburgi*, which inhabits the adjacent Karpathos and Kasos, and *M. bicolor* with its nominotypical subspecies described from Rhodos and the subspecies *M. b. crassiflagellum* described from Naxos. It is also notable that only 4 species, namely *B. stuxbergi*, *M. brachyurum*, *M. taygeti* and *M. rossicum*, occur both on islands and on either European or Asian mainlands. *B. stuxbergi* is widely distributed in Greece and Italy; *M. brachyurum* is represented on Thasos with its subspecies *M. b. thassensis*, while the nominotypical subspecies inhabits the Caucasian region; *M. taygeti* occurs on the Peloponnese; *M. rossicum rossicum* is widely distributed in South Russia and the Ukraine, while *M. r. strandschanum* has been reported from south Bulgaria and northeast continental Greece, apart from the single record from Samothraki.

The Aegean Islands seem to support a high number of endemics of the Brachyiulini tribe, the most outstanding of which are the two species of *Enghophyllum* gen. nov. Compared to a number of biogeographic and phylogeographic papers dealing with different invertebrate groups from the Aegean region (e.g., Douris *et al.* 2007; Fattorini & Fawles 2005; Sfenthourakis 1996; Welter-Schultes & Williams 1999) the above described distribution pattern of the Aegean Brachyiulini is especially similar to that observed by Heller (1976). He found most Aegean species of the terrestrial gastropod family Enidae to occur only on one or several adjacent islands, which is considered to reflect the lack of active immigration in recent geological times. These biogeographic similarities could be explained with the very limited dispersal abilities characteristic of millipedes and land snails in general. Another reason may be the rather weak ecological specialization common to both groups. Thus, their current distribution would be less affected by the presence/absence of particular plant communities or habitat degradation, unlike the case with, e.g., the central Aegean Oniscidea (Sfenthourakis 1996), and would more clearly reflect the geological events that took place in the Aegean region. In this respect the record for *E. naxium* from east Mavri may present interesting information in terms of further revealing the biogeographic affiliations of this group of several small islands (Kinaros, west and east Mavri and Levitha), positioned between the Cyclades and the Dodecanese although officially ascribed to the latter. Sfenthourakis (1996) suggested that Mavri is biogeographically related to several scattered islands in the south Cyclades, while Levitha has more in common with the other Dodecanese islands. However, the overall scarce faunistic data hamper any firm conclusions being reached about the islets' paleogeographic history.

In spite of the rather few distribution records for the new genus, as well as the insufficiently investigated millipede fauna of the Greek islands in general, we may suppose that the genus described here represents a distinct lineage of Brachyiulini that has developed in relatively long-lasting isolation, as there are currently no apparent closely related forms in the Balkans or in Anatolia. The relict character of the Aegean fauna has already been demonstrated for other invertebrate groups like tenebrionid beetles (Fattorini & Fawles 2005) and land snails (Heller 1976; Welter-Schultes & Williams 1999).

In conclusion, it can be assumed that *Enghophyllum* gen. nov. confirms the importance of the Aegean Islands together with south Greece and west Turkey for the evolution of the millipede tribe Brachyiulini, being inhabited by both highly distinct local forms, as well as by members of (sub)genera and species groups found in other regions – evidence of successive processes of migration and vicariance resulting

in intense speciation. On the other hand, the dominant position of the tribe in terms of species richness among Diplopoda from the region, combined with a high rate of endemism, provide good reasons for using the group as a model for further elucidation of the complicated paleogeographic history of the Aegean Archipelago.

## Acknowledgements

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