An Approach to the Revision of the East Asian Millipede Genus *Anaulaciulus*

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**ABSTRACT**

The millipede genus *Anaulaciulus* Pocock, 1895 (Juliida: Julidae) comprises 44 species, distributed in Eastern Asia. Based on fresh studies of numerous samples, type material and literature, a comprehensive overview of the genus is proposed. A list of the presently known species is given, and a preliminary grouping is outlined on the basis of their posterior gonopod structure. Other external and internal characters, such as penis, gonopod promerit and female vulva structure, coloration, size, and shape of the preanal projection are discussed and evaluated. Two examples of evolutionary gonopod transformation series are presented and illustrated.

**RÉSUMÉ**

**Essai de révision du genre est-asiatique *Anaulaciulus*.**

Le genre *Anaulaciulus* Pocock, 1895 (Diplopoda, Julida, Julidae) comprend 44 espèces réparties dans l’Est asiatique. La présente révision, basée sur l’examen récent de nombreux exemplaires, permet de présenter une liste dans laquelle les espèces sont séparées en groupes provisoirement basés sur la structure des gonopodes postérieurs. D’autres caractères, externes et internes, tels que le pénis, la prométrie des gonopodes, la structure des vulves, la coloration, la taille, et la forme du telson sont discutés et évalués. Deux exemples de transformation évolution des gonopodes sont présentés et illustrés.

**INTRODUCTION**

The genus *Anaulaciulus* at present consists of 44 nominal species (with 4 proposed subspecies) including 10 forms recently described from the Southern Himalaya region (KORSÓS, in press). Part of the original descriptions of the other species are rather old and not properly detailed, type material of those is usually difficult to obtain. As the range of the genus (see below) implies, there may certainly be a large number of yet undiscovered species. However, considering the available material, a preliminary review of the genus seems not to be premature.

The distribution of the species in the genus includes the temperate zone of Eastern Asia: from Pakistan to the Russian Far East, through Nepal, northern India, Sikkim, Tibet, northeastern China and Korea, including Hong-Kong and Taiwan. Numerous forms occur also in Japan, south of Hokkaido (Honshu, Shikoku, Kyushu, Ryukyu Islands, Bonin Islands). To the contrast of the other widespread Eastern Asian julid genus *Nepalmatoiulus*, *Anaulaciulus*
does not seem to penetrate into the tropical regions, it is confined to the temperate zone or high altitudes.

The genus name itself was introduced by POCK in 1895, and subsequently generally overlooked. The majority of the species belonging now to Anaulaciuus were originally described in Fusidius Attems, 1909, and only in 1966 did CAUSEY recognize the synonymy with a redescription of the two POCK's species (paludicola and vallicola).

Anaulaciuus belongs in the tribe Brachyiulinia, which can be characterized as follows:

Julidae (Brachyiuliniae) without a free mesomerit on the posterior gonopod, with a well-developed flagellum, and generally compressed gonopods in the antero-posterior direction. About 24 genera are enlisted in this tribe, however, their relationship has not yet been completely clarified.

The genus Anaulaciuus can be defined on the basis of some peculiarities externally as well as in the gonopod conformation. The animals have no metazonal setae, no cheek lobes expanded in the males. Male gonopod promerites are characteristically flattened, scale-like, a rudiment of the telopodit is well visible. Posterior gonopods are rather simple, elongated, in situ always protruding from beneath protecting promerites, and have several longitudinal, slightly arched lamellae. The penis is long, bifurcate in every species; this character seems to be a unique apomorphy for the genus in the entire millipede order Julida; even the closest relatives of the genus in the tribe Brachyiulinia have a completely different penis (Figs 1-3). The long, leaf-like structure (differently developed in the different species) seems to be homologous with the apical membrane in the other species, and the opening of the seminal groove is situated most probably caudally at the basis of the "leaves".

The female vulval characters show also some peculiarities as compared to other members of the tribe. They are slightly compressed in the antero-posterior direction (others are more or less cylindrical), the well-separated operculum is always longer than bursa and apically provided with two lateral cusps (often also a median one). The median cleft on bursa is deep, the apodematic tube without secondary branches, the ampulla usually without an appendix.

A more detailed characterization of the genus is given elsewhere (KORSÖ, in press).

There are very few works devoted to a summary or clarification of the internal relationships of Anaulaciuus. An identification key is given to the species known at that time by VERHOEFF, first in 1937 (for five species), then in 1941 (for 9 species, VERHOEFF, 1941a), and by TAKAKUWA (1941, for 16 forms). They are all based mainly on minor gonopodal character details, and not very useful, especially if one regards the different quality of the descriptions and the possible morphological variations in the populations. ENGHOFF (1986) lists 28 nominal species and 6 subspecies with comments on their distribution. He establishes the synonymies of A. ciliatus Shinohara, 1960 and F. trilobus quemoyensis Wang, 1963. Apart from these, no attempt for the revision of the entire genus has been made.

**REVIEW OF THE SPECIES**

In the followings, a renewed alphabetical list of the presently known species in the genus is given, together with a name history and distributional data of every species. Illustrations wherever available are also referred to.

1. **Anaulaciuus acaudatus** KORSÖ, in press
   Anaulaciuus acaudatus: KORSÖ, in press (Figs 26-28)
   India: Sikkim.

2. **Anaulaciuus acutus** (Takakuwa, 1941)
   Fusidius acutus: TAKAKUWA, 1941 (Figs 2-3)
   Anaulaciuus acutus: ENGHOFF, 1986
   Japan: Honshu.

3. **Anaulaciuus attensis** (Verhoeff, 1941)
   Fusidius attensis: VERHOEFF, 1941a (Figs 31-33)
   Anaulaciuus attensis: ENGHOFF, 1986
   Japan: Honshu.
4. Anaulacius bilineatus Korsós, in press
Anaulacius bilineatus: Korsós, in press (Figs 2-4, 6, 9, 11, 29-33)

5. Anaulacius bilobus (Takakuwa, 1941)
Fusius bilobus: TAKAKUWA, 1941 (Figs 10-11)
Anaulacius bilobus: ENGHOFF, 1986

6. Anaulacius capillatus (Takakuwa, 1941)
Fusius capillatus: TAKAKUWA, 1941 (Figs 12-13)
Anaulacius capillatus: ENGHOFF, 1986

7. Anaulacius cornutus (Takakuwa, 1941)
Fusius cornutus: TAKAKUWA, 1941 (Figs 17-18)
Anaulacius cornutus: ENGHOFF, 1986

8. Anaulacius enghoffi Korsós, in press
Anaulacius enghoffi: KORSÓS, in press (Figs 34-41)

9. Anaulacius golovatchi Mikhaijlova, 1982
Anaulacius golovatchi: MIKHAJLOVA, 1982 (Fig. 2)

10. Anaulacius hirosaminus (Attems, 1909)
Fusius hirosaminus: ATTEMS, 1909 (Figs 76-78)
Anaulacius hirosaminus: ENGHOFF, 1986

11. Anaulacius inaequipes Enghoff, 1986
Anaulacius inaequipes: ENGHOFF, 1986 (Figs 1-4)
Anaulacius inaequipes: KORSÓS, in press (Figs 20-25)

12. Anaulacius kashmiirensis Korsós, in press
Anaulacius kashmiirensis: KORSÓS, in press (Figs 42-47)

13. Anaulacius kiusiensis (Verhoeff, 1941)
Fusius kiusiensis: VERHOEFF, 1941a (Figs 34-36)
Anaulacius kiusiensis: ENGHOFF, 1986

14. Anaulacius komatsui (Shinohara, 1957)
Fusius komatsui: SHINOHARA, 1957 in TAKAKUWA & SHINOHARA, 1957 (Fig. 2)
Anaulacius komatsui (Takakuwa & Shinohara, 1957): ENGHOFF, 1986

15. Anaulacius koreacolus Jedryczkowski, 1982
Anaulacius koreacolus: JEDRYCZKOWSKI, 1982 (Figs 28-36)
Anaulacius koreacolus: ENGHOFF, 1986

16. Anaulacius koreanus (Verhoeff, 1937)
Fusius koreanus: VERHOEFF, 1937 (Figs 4-8)
Fusius koreanus koreanus Verhoeff, 1937: PAIK, 1976
Anaulacius koreanus: ENGHOFF, 1986
Anaulacius koreanus koreanus: LIM, 1988

16.1. Anaulacius koreanus boninensis (Verhoeff, 1939)
Fusius koreanus boninensis: VERHOEFF, 1939a (Figs 16-17)
Anaulacius koreanus boninensis: GOLOVATCH, 1980 (Figs 1-2)
Anaulacius koreanus boninensis: ENGHOFF, 1986

16.2. Anaulacius koreanus tuberculatus (Takakuwa, 1941)
Fusius koreanus tuberculatus: TAKAKUWA, 1941 (Fig. 19)
Anaulacius koreanus tuberculatus: ENGHOFF, 1986

17. Anaulacius kuritai (Murakami, 1966)
Fusius kuritai: MURAKAMI, 1966 (Fig. 1)
Anaulacius kuritai: ENGHOFF, 1986

18. Anaulacius longus (Takakuwa, 1941)
Fusius longus: TAKAKUWA, 1941 (Figs 6-7)
Anaulacius longus: ENGHOFF, 1986

19. Anaulacius nepalensis Korsós, in press
Anaulacius nepalensis: KORSÓS, in press (Figs 1, 3, 7, 10, 48-52)

Nepal.

Japan: Kyushu.

Japan: Honshu.

Japan: Kyushu.

China: Kansu.

Russia: Far East, Maritime Province; recently reported from North Korea as well (MIKHAJLOVA, 1993).

Japan: Hiro Sami.

Burma.

India: Kashmir.

Japan: Kyushu.

Japan: Honshu.

Korea: Sunchon and Hyangsan districts.

Korea: Hoko.

Japan: Bonin Islands, Ryukyu Islands; Korea (TAKAKUWA, 1941; PAIK, 1976; LIM, 1988; GOLOVATCH, 1980).


Japan: Shikoku.

Japan: Akiyoshi; Korea (LIM, 1988).

Nepal.
20. **Anaulaciulus niger** Korsós, in press
   *Anaulaciulus niger*: KORSÓS, in press (Figs 53-58)

21. **Anaulaciulus okinawae** Shinohara, 1990
   *Anaulaciulus okinawae*: SHINOHARA, 1990 (Fig. 1)

22. **Anaulaciulus onychophora** (Takakuwa, 1942)
   *Fusius onychophora*: TAKAKUWA, 1942 (Figs 1-2)
   *Anaulaciulus onychophora*: ENGHOFF, 1986

23. **Anaulaciulus otigonopus** Zhang, 1993
   *Anaulaciulus otigonopus*: ZHANG, 1993 (Figs 1-7)
   *Anaulaciulus otigonopus*: KORSÓS, 1994
   *Anaulaciulus otigonopus*: KORSÓS, in press

24. **Anaulaciulus pakistanus** Korsós, in press
   *Anaulaciulus pakistanus*: KORSÓS, in press (Figs 59-60)

25. **Anaulaciulus paludicola** Pocock, 1895
   *Anaulaciulus paludicola*: POCOCK, 1895
   *Anaulaciulus paludicola*: CAUSEY, 1966 (Figs 1-6)

26. **Anaulaciulus pinetorum** (Attems, 1909)
   *Fusius pinetorum*: ATTEMS, 1909 (Figs 14-16, 69-75)
   *Fusius pinetorum*: SHINOHARA, 1960 (Fig. 18)
   *Anaulaciulus pinetorum*: ENGHOFF, 1986

26.1 **Anaulaciulus pinetorum nivalis** (Verhoeff, 1941)
   *Fusius pinetorum nivalis*: VERHOEFF, 1941b (Figs 8-10)
   *Fusius ciliatus*: SHINOHARA, 1960 (Figs 14-17); ENGHOFF, 1986
   *Anaulaciulus pinetorum nivalis*: ENGHOFF, 1986

27. **Anaulaciulus quadratus** (Takakuwa, 1941)
   *Fusius quadratus*: TAKAKUWA, 1941 (Figs 14-16)
   *Anaulaciulus quadratus*: TAKANO, 1978
   *Anaulaciulus quadratus*: ENGHOFF, 1986

28. **Anaulaciulus riedeli** Jedryczkowski, 1982
   *Anaulaciulus riedeli*: JEDRYCZEKOWSKI, 1982 (Figs 19-27)
   *Anaulaciulus riedeli*: ENGHOFF, 1986

29. **Anaulaciulus ryugadensis** Shinohara, 1990
   *Anaulaciulus ryugadensis*: SHINOHARA, 1990 (Fig. 2)

30. **Anaulaciulus simodanu**s (Takakuwa, 1941)
   *Fusius simodanu*s: TAKAKUWA, 1941 (Figs 8-9)
   *Anaulaciulus simodanu*s: ENGHOFF, 1986

31. **Anaulaciulus simplex** Verhoeff, 1936
   *Fusius simplex*: VERHOEFF, 1936
   *Anaulaciulus simplex*: SHINOHARA, 1973
   *Anaulaciulus simplex*: ENGHOFF, 1986

32. **Anaulaciulus takakuwi** (Verhoeff, 1941)
   *Fusius takakuwi*: VERHOEFF, 1941a (Figs 37-38)
   *Anaulaciulus takakuwi*: ENGHOFF, 1986

   subspecies:
   **Anaulaciulus takakuwi coloratus** (Verhoeff, 1941)
   *Fusius takakuwi coloratus*: VERHOEFF, 1941a (Fig. 39)
   *Anaulaciulus takakuwi coloratus*: ENGHOFF, 1986

33. **Anaulaciulus takano** Shinohara, 1990
   *Anaulaciulus takano*: SHINOHARA, 1990 (Fig. 3)

34. **Anaulaciulus tibetanus** Korsós, in press
   *Anaulaciulus tibetanus*: KORSÓS, in press (Figs 61-63)

35. **Anaulaciulus tigris** Korsós, in press
   *Anaulaciulus tigris*: KORSÓS, in press (Figs 5, 12, 64-69)

36. **Anaulaciulus tonggosanensis** Paik, 1976
   *Fusius longus*: TAKAKUWA, 1941: sensu PAIK, 1963
   *Fusius tonggosanensis*: PAIK, 1976 (Figs 1-11)

Nepal.

Japan: Ryukyu Islands.

Japan: Honshu.

China: Hunan Province, Changsa.

Pakistan: Swat.

China: Wo-Lee Lake.

Japan: Honshu.

Japan: Honshu.

Japan: Shikoku.

Japan: Honshu.

Japan: Honshu, in caves widely distributed (SHINOHARA, 1973); Taiwan (WANG, 1963; SHINOHARA, 1973).

Japan: Honshu.

Japan: Honshu, Niijima Island.

Japan: Honshu.

China: Tibet; India: Assam.

Pakistan: Swat.

Korea: Mt. Tonggo-san (LIM, 1988).
37. Anaulaciulus tonginus (Karsch, 1881)
    *Iulus tonginus*: KARSH, 1881
    Anaulaciulus tonginus: ENGHOFF, 1986
    Anaulaciulus tonginus: KORSOS, 1994 (Figs 1-8)
    Fusiulus trilebus *khuae* Wang, 1963: KORSOS, 1994

38. Anaulaciulus topali Korsós, in press
    Anaulaciulus topali: KORSOS, in press (Figs 70-75)

39. Anaulaciulus trapezoidus (Wang, 1955)
    *Fusiulus trapezoidus*: WANG, 1955 (Fig. 3)
    Anaulaciulus trapezoidus: ENGHOFF, 1986

40. Anaulaciulus trigonalis (Takakuwa, 1941)
    *Fusiulus trigonalis*: TAKAKUWA, 1941 (Figs 4-5)
    Anaulaciulus trigonalis: ENGHOFF, 1986

41. Anaulaciulus trilobus (Wang, 1963)
    *Fusiulus trilobus* quemoyensis: WANG, 1963
    Anaulaciulus trilobus: ENGHOFF, 1986

42. Anaulaciulus vallicola (Pocock, 1895)
    *Iulus vallicola*: POCOCK, 1895 (Fig. 13)
    Anaulaciulus vallicola: CAUSEY, 1966 (Fig. 7)

43. Anaulaciulus yamashinai (Verhoeff, 1939)
    *Fusiulus yamashinai*: VERHOEFF, 1939b (Figs 1-3)
    Fusiulus yamashinai: Verhoeff, 1941a (Figs 40-42); ENGHOFF, 1986
    Fusiulus insularum: Verhoeff, 1941a; ENGHOFF, 1986
    Fusiulus yamashinai: TAKAKUWA, 1941 (Fig. 1)
    Anaulaciulus yamashinai: ENGHOFF, 1986

44. Anaulaciulus yosidanus (Takakuwa, 1941)
    *Fusiulus yosidanus*: TAKAKUWA, 1941 (Figs 20-21)
    Anaulaciulus yosidanus: ENGHOFF, 1986

INTRAGENERIC RELATIONSHIPS

The only internal classification of the genus appears in the division by VERHOEFF (1941b) where he, on the occasion of a new subspecies, *Fusiulus pinetorum nivalis*, erected the subgenus *Parfusiulus* for all the other members of the genus. The only species, *pinetorum* (with the subspecies *nivalis*) remained in the subgenus *Fusiulus* s. str. in his sense. However, the distinguishing character (i.e. two hairy fields on the mesal and lateral lamellae of the opisthomerites) seems not to be warranted, especially in the light of a more careful study of the gonopodal details in other species. As a result, virtually all species of the genus have more-or-less hairs on their opisthomerit lamellae.

According to an examination of the shape of the telopodites of the posterior gonopods, the following preliminary species-groups in the genus can be presented.

1. *yamashinai*-group (cf. Figs 8-11): *acutus, bilobus, cornatus, komatsui, onychophora, pinetorum, quadratus, trigonalis* and *yamashinai*

2. *paludicola*-group (cf. Figs 5-6): *koreacolus, longus, paludicola, riedelii, simodanus* and *tonggosanensis*

3. *koreanus*-group: *koreanus, okinawaensis, trapezoidus*

4. *hirosaminus*-group: *hirosaminus, kuritai*

5. *simplex*-group (cf. Fig. 7): *atemsis, simplex*

6. *tonginus*-group: *otigonopus, tonginus, trilobus*

7. *inaequipes*-group: *acaudatus, bilineatus, enghoffi, inaequipes, kashmirensis, nepalensis, niger, pakistanus, tibetanus, tigris and topali*

The species *takakuwai* can be considered as a bridge-species between the *paludicola*-group and the *koreanus*-group (based purely on gonopod comparison).
Six species could not be inserted in the groups above: capillatus, golovatchi (Fig. 4), kiusiensis, ryugadensis, takanoi, yosidanus. In some cases their gonopods are so peculiar (e.g., in takanoi) that even their validity within the genus Anaulaciulus may be question-marked. (The original description of this species does not deal with some important features like penis structure, etc.).

One species, vallicola is known only by female, and although the type specimen has been redescribed by Causey (1966) and also seen by the author, nothing can be said about its position in the genus.

Based on some fresh material, kindly loaned by Dr. H. Ono (National Science Museum, Tokyo) some preliminary sketches are given to illustrate two main general pattern series. Figures 5 to 7 (samples from Korea and Japan) show the line of complete reduction of the opisthomerites, from a "paludicola"-type gonopod to a simple "needle". Anaulaciulus golovatchi (Fig. 4, drawn from a paratype kindly loaned by Dr. S. I. Golovatch, Moscow) may perhaps also be inserted in this series.

The other line is more complicated but some characteristics can be observed. The lateral lamellae of the opisthomerit appears as a "shoulder" (Fig. 8) and later, through a series of intermediates (Figs 9-11), develops into a broad "wing" (Fig. 12) as it is seen in the inaequipes-group. Although all this drawings are based on species originated from Japan, there is a striking resemblance between the gonopods of the specimen from Honshu (Gifu) and those of the
members of the *inaequipes*-group (cf. KORSÓS, in press). However, the lack of a proper “beak” surely allocates it in another relationship. The samples investigated for this study are certainly including several new forms, which will be dealt in future investigations.

It was already pointed out elsewhere (KORSÓS, 1994), that *Anaulaciulus tonginus* (and the similar - maybe synonymous - species, *otigonopus* and *trilobus*) is believed to have a somewhat peculiar position in the genus. Not only its intermediate penis and gonopod structure (thick, antero-posteriorly not so flattened promerites; peculiar telopodits with a beginning of a “beak” yet densely haired), but also its central geographical distribution (Hong-Kong, Taiwan, and maybe other parts of southeastern China) implies that it is close to the theoretical ancestor of the whole genus.

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**FIGS 8-12.** — Left opisthomerite, frontal view. - 8: Specimen from Japan, Honshu, Chojaga mori. - 9: Specimen from Japan, Kyushu, Nagasaki. - 10: Specimen from Japan, Kyushu, Yaku-shima. - 11: Specimen from Japan, Kyushu, Kumamoto. - 12: Specimen from Japan, Honshu, Gifu. Scale 0.5 mm.

**CONCLUSIONS**

It is clear from the present observations, that the shape of the scale-like promerit is very variable in the populations and that it is not a reliable character for distinguishing species. This was already introduced by MIKHAILOVA (1982), and further discussed by KORSÓS (in press). Unfortunately, descriptions of former species, in some cases, have been exclusively based on the shape of the promerit (e.g., *acatus*, *bilobus* & *quadratus*, all by TAKAKUWA, 1941). The degree of the morphological variability of the opisthomerites is still to be defined, and a clarification may well be resulted in a number of synonymies in the species-groups outlined above.

Female (vulval) characters, as often neglected before, are also in urgent need to redescribe. The species in the *inaequipes*-group (KORSÓS, in press) show relatively consistent pattern in the internal structure of bursa, usually having a simple or slightly curved apodematic tube and a more-or-less sphaerical ampulla; whereas other species may have more complicated apodematic tube (*golovatchi*), or an ampulla strongly elongated (*tonginus*, *riedeli*, *kiosiensis*) or with a distinct appendix (*koreanus*).

As it was shown by the analysis of the *inaequipes*-group, external characters have usually an emphasized importance in distinguishing the different species. General body colouration
(longitudinal stripes e.g., in bilineatus, bright yellow ground colour with dark brown blotches ordered according to pro- and metazona: as in tigris and pakistanus) is more characteristic to several species than the gonopod conformation, and may also be more useful in separating them. Outside the inaequipes-group, one can also find similar feature: golovatchi, paludicola, tonginus and yamashinai show three black, longitudinal stripes.

The shape of the epiproct may also help in distinguishing the species, while members of the inaequipes-group never have a preanal project turned upwards (usually it is short, straight, or missing), the same character state, to a different degree, is not rare in the other continental and in the Japanese species (e.g., in golovatchi, koreacolus, riedeli, ryugadensis, takanoi & tonginus).

In some cases, maybe due to coexistence, significant size differences appear in closely related species-pairs (nepalensis-niger, pakistanus-tigris). This phenomenon is analyzed in more detail elsewhere (KORSÓS, in press).

Future investigations should aim at the more accurate characterization of the species, and, with the accumulation of large material from the geographically remote areas, also from Japan, the internal relationships of this highly diverse and complex genus will become possible to be clarified.

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REFERENCES


WANG, Y. M., 1963. — Serica 1q: Millipedes and centipedes of Quemoy, Fukien Province, and Taiwan Island, Botel Tobago (Lan Yu), Taiwan Province and of Singapore. *Quart. J. Taiwan Mus.*, 16 : 89-96.